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Joint EPA/UMTA/FEA Strategy for Urban Transportation and Air Quality. Volume 4. Information Data Base: Status of Urban Congestion, Air Pollution, and Energy Use

Interplan Corporation, Santa Barbara, California

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The objective of this four-volume study is to formulate a basis for the design of a joint interagency action program which would simultaneously improve urban mobility and air quality and conserve petroleum resources.

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This fourth volume contains INTERPLAN's initial definition of the transportation-related urban problems now faced by UMTA, EPA, and FEA, and their authority to cope with these problems. The current status of transportation-related urban congestion, air pollution, and energy usage is analyzed on a national level, and the future status likely to obtain if present trends continue unchecked is projected. Congestion and air pollution is also examined in four cities: Los Angeles, Philadelphia, Seattle, and Baltimore. The goals, authority, and programs of the three agencies are reviewed to define the potential for a joint interagency action program. A preliminary bibliographic listing is included as an Appendix; the study's final 376-item bibliography is contained in Volume 1.

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Volume 4: Information Data Base: Status of Urban Congestion, Air Pollution, and Energy Use

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SECTION 1

INTRODUCTION

PURPOSE AND CONTENTS OF THE STUDY

This is the fourth volume of a four-volume report covering the results of INTERPLAN Corporation's study, Joint EPA/UMTA/FEA Strategy for Urban Transportation and Air Quality (Contract N00140-74-C-6026). The premise of the study was that the administrative independence of UMTA, EPA, and FEA should not obscure the interdependence of the goals of these three agencies: to improve urban mobility, upgrade the quality of urban air, and assure an adequate supply of energy. More specifically, it was felt that these three agencies can accomplish more by acting jointly on mutual problems than they can by following separately conceived programs.

In the broadest terms, it can be said that the common issue around which all three agencies' policies revolve is the use of the private auto, or auto management, involving both incentives and penalties to catalyze a change in existing urban travel characteristics. Because today's urban mobility, which is UMTA's primary goal, is based on the private automobile, it has been attained at the expense of excessive air pollution—EPA's concern—and the consumption of an alarmingly large proportion of the nation's petroleum resources—FEA's concern. When traffic congestion restricts urban mobility, unacceptable economic and social losses result as well as additional amounts of air pollution and gasoline consumption. The present shortage and future natural limitations in petroleum supply portend the eventual end of urban mobility based on vehicles dependent on gasoline propulsion. Thus, all three issues—mobility, air quality, petroleum use—are irrevocably interrelated in a kind of chain reaction relationship initiated by the overwhelming orientation of urban travel to the private, gasoline-powered automobile.

The objective of this study, therefore, is to formulate a basis for the design of a joint action program which would simultaneously improve urban mobility and air quality and conserve petroleum resources. To accomplish this end, the study evaluates current and proposed policy actions directed toward attaining the goals of urban mobility, air quality, and energy conservation (Volume 1); evaluates the trends opposing these goals, i.e., urban congestion, vehicle pollutant emissions, and vehicular energy use (Volume 4); and explores future options in urban transportation modal mixes (Volume 2) and the use of dual mode technology (Volume 3).

The study's four volumes are:

Volume 1: Joint Action Programs
Volume 2: Public-Private Urban Transportation Modal Mixes
Volume 3: The Potential of Dual Mode
Volume 4: Information Data Base: Status of Urban Congestion, Air Pollution, and Energy Use.

An unnumbered summary volume has also been prepared.

This fourth volume contains INTERPLAN's initial definition of the transportation-related urban problems now faced by UMTA, EPA, and FEA, and the federal authority available to cope with these problems. Although this volume was the first in the study to be written, it is presented as the last volume in the series because it constitutes a kind of technical and statistical appendix. The analysis it contains represents the basic spadework required to understand the nature and extent of the problems addressed, which is fundamental to the Volume 1 analysis of recommended solutions, and to establish base figures for the current and projected degree of congestion and amounts of pollutants emitted and energy consumed against which to measure the impacts of offsetting actions and of future modal mixes in Volumes 1 and 2.

Specifically, in this volume, the current status of transportation-related urban congestion, air pollution, and energy usage is analyzed, and the future status likely to obtain if present trends continue unchecked is projected. To illustrate the high degree of specificity of these problems to individual urban areas, the status of congestion and air pollution is examined in four cities: Los Angeles, Philadelphia, Seattle, and Baltimore. The goals, authority, and programs of the three federal agencies are reviewed to define the potential scope of action available for a joint interagency urban transportation and air quality action program. Because this volume was the first to be written, the bibliographic listing it includes is a preliminary one containing the 184 documents reviewed to prepare this volume. The comprehensive 376-item listing in Volume 1 is the final bibliography for the study.

The contents of the other three volumes of this report are briefly described below.

Volume 1 represents the culmination of the study effort to attain the study objectives. In the first part of Volume 1, basic relationships among principal strategies and actions which impact on the transportation-related goals of UMTA, EPA, and FEA are summarized in a matrix display, and each item is ranked to assess its impact on six subgoals, or offsetting phenomena, in the near and long term. On the basis of this ranking, two synergistic joint action programs are presented. The second part of Volume 1 presents a detailed review and evaluation of information on 55 specific actions, including documented experience, impacts on goals (mobility, air quality, energy conservation), and the overall evaluation of each action. Volume 1 also contains INTERPLAN's final comprehensive bibliography.

The second volume addresses issues related to future transportation options. It presents an algorithm for calculating the impacts on transportation energy use and pollutant emissions of alternative urban transportation mixes. The use of this algorithm is demonstrated first by building a consistent database representing a maximum conceivable diversion by 1990 of urban auto travel to bus, rail, and para-transit modes, and then by calculating the change in energy use and pollutant emissions implied by the maximum diversion case relative to the no-diversion case. This exercise, intended to apply to national policy analysis, is complemented by a discussion of issues, tradeoffs, and methodologies relevant to the local determination of a balanced modal mix in an individual metropolitan area.

The third volume expresses INTERPLAN's best judgment about the applicability, timing, and impact of dual mode urban transportation technologies, prefaced by a short overview and comparison of the propulsion and energy use characteristics of conventional and future urban transportation modes.

SCOPE OF THIS VOLUME

The scope of this volume is limited to an examination of those aspects of air pollution and energy usage which are related to UMTA's goal of providing for urban mobility. Explicitly excluded, therefore, are strictly EPA/FEA interface problems such as the impact on energy production of EPA regulation of stationary energy source emissions. Also excluded is the analysis of the reciprocating effects of mobile emission controls and strategies on automotive fuel consumption, except to the extent that these effects, by contributing to the rising cost of private vehicular travel, may restrict urban mobility or influence a shift to increased transit patronage.

Because conditions of urban congestion and air pollution are highly specific to individual urban areas, the best portrayal of the current and future status of these conditions would be obtained by examining these problems on a city-by-city basis. However, at the proposal phase the scope of this study was limited to an analysis of only four cities of high mutual concern to UMTA and EPA: Los Angeles, Seattle, Philadelphia, and Baltimore. The rationale for the selection of these cities is presented in Section 3.

ORGANIZATION OF THIS VOLUME

This volume consists of three major sections and 6 appendices. Section 2 presents information on a nationwide basis concerning the current status of congestion, air pollution and energy usage, past trends in these problem areas, and the projected future status which is likely to be reached in each if past trends are left unchecked. Section 3, utilizing a parallel approach, focuses on the past, current and future status of congestion and air pollution in the four U.S. cities of high mutual interest to UMTA and EPA mentioned above. The federal goals, authority and programs of EPA, UMTA, and FEA in the three problem areas addressed in this study are documented in Section 4. The implications of current trends on the goals and activities of these agencies are also briefly discussed in Section 4.

Appendix A presents the study's work statement for reference purposes. Appendix B contains bibliographic citations of the 184 references consulted in the preparation of this volume. References cited in each section of the report are also listed at the end of each section. Appendices C and D contain supporting data for the information presented in Section 2. Appendices E and F contain supporting data for the Section 3 information base.

SECTION 2

PAST, CURRENT, AND FUTURE STATUS OF URBAN CONGESTION, AIR POLLUTION AND ENERGY USE

INTRODUCTION

The purpose of this section is to present as objectively and concisely as possible information on the past and current nationwide status of transportation-related urban congestion, air pollution and energy use and, based on this information, to project the future status in each of these problem areas which will result if no offsetting strategies are implemented. The information presented here comprises the database for the subsequent nationwide analysis of the effect of various proposed policies and solutions on each of the problem areas and primary and secondary interacting effects.

The task of selecting the information to be presented was unexpectedly difficult for the following three reasons:

1. Current interest and controversy in each of the problem areas has resulted in a plethora of literature on numerous facets of each problem not all of which are germane to the objectives of this study.
2. No single authority in any of the problem areas has presented the problem from a viewpoint accepted by all; biases are evident in most representations.
3. Major differences in values of basic and presumably factual data are documented by different sources in each of the problem areas.

As a result, the selection process itself entailed, first, a survey of the relevant literature on each subject. Next, the information required to accomplish the study objectives was defined and pertinent information in the literature was compared and analyzed. Any discrepancies noted at this stage of the process were examined and further sources were reviewed to ensure, to the extent possible, that the values selected for use were verifiable. The comprehensive bibliography of sources reviewed comprises Appendix B. References used for the database presented in this section are listed at the end of the section (page 72), and referred to by numbers in parentheses in the text. An attempt was made to cite only the most authoritative source; however, this does not imply that other sources in the bibliography did not present the same information. No attempt has been made to document and compare

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all discrepancies located in the literature, except in those instances where a discussion of opposing viewpoints bears on the study objectives.

URBAN TRAFFIC CONGESTION: CURRENT STATUS AND PAST AND FUTURE TRENDS

In considering the problem of urban congestion a clear distinction must first be made between the underlying causes of urban congestion and their resulting effects on urban mobility. Causes for urban congestion lie in the complex set of interrelationships among the basic determinants of travel demand: income (and its distribution), land-use patterns, and the characteristics of the transportation system, the magnitude of the demand being largely determined by population size. The interrelationships among these determinants are further complicated by other factors such as feedback effects, public policies, and changes in personal desires and life styles. Naturally, these underlying causes are important in this study in the subsequent analyses of the impacts of various offsetting phenomena. However, the purpose of this section is to present all current and relevant information on the resulting effects on urban mobility—as these effects can be traced from the past, as they have been manifested in the present status of urban mobility, and as they may be expected to continue if their trends are left unchecked.

Past Trends

Increasing dependence on the private automobile to satisfy travel demands coupled with a decline in the use and availability of transit alternatives have been the major trends associated with the current status of urban congestion. Congestion has been a problem throughout history in large urban areas when growing travel demand outpaced the expansion of the carrying capacity of the surface street network, whatever vehicles were in use. The principal mitigating action in alleviating congestion in recent imes has been the extension and expansion of the roadway system. Past trends in these three phenomena are documented below.

TRENDS IN MOTOR VEHICLE USE. Statistics on motor vehicle travel from 1950 to 1971 are given in Table 1. From Table 1 it can be observed that the annual rate of increase in the number of automobiles and buses from 1950 to 1971 has been somewhat less than the rate of increase in the number of cargo vehicles,

Table 1. Trends in motor vehicle travel, 1950-1971.

	1950	1955	1960	1965	1968	1969	1970	1971
Automobiles								
Passenger cars (millions)	40.3	52.1	62.3	75.3	83.6	86.9	89.2	92.8
Change[1](%)		*5.8*	*3.9*	*4.2*	*3.7*	*3.9*	*2.6*	*4.0*
Miles traveled/vehicle (000)	9.02	9.36	9.45	9.39	9.63	9.78	9.98	10.12
Change (%)		*.75*	*Neg.*[4]	*Neg.*	*Neg.*	*1.6*	*2.0*	*1.4*
Total VMT[2] (billions)	364	493	588	706	806	850	891	939
Change (%)		*7.1*	*3.9*	*4.0*	*4.7*	*5.5*	*4.8*	*5.4*
Urban VMT (billions)	183	234	285	378	439	466	495	525
Change (%)		*5.6*	*4.4*	*6.5*	*5.4*	*6.2*	*6.2*	*6.1*
Urban VMT/Total VMT (%)	50.3	47.5	48.5	53.4	54.5	54.8	55.6	55.9
Cargo Vehicles								
Vehicles (millions)	8.4	10.4	11.9	14.8	17.0	17.9	18.7	19.8
Change (%)		*4.8*	*2.9*	*4.9*	*5.0*	*5.3*	*4.5*	*5.9*
Miles traveled/vehicle (000)	10.78	9.62	9.65	11.59	11.57	11.57	11.45	11.47
Change (%)		*-2.2*	*Neg.*	*4.0*	*Neg.*	*-0-*	*-1.0*	*Neg.*
Total VMT (billions)	90.6	109	126	171	182	207	215	227
Change (%)		*4.1*	*3.1*	*7.1*	*2.1*	*13.7*	*3.4*	*5.6*
Urban "single unit" VMT (bil.)	N/A	N/A	N/A	59.2	61.5	64.9	68.8	73.0
Change (%)					*1.3*	*5.5*	*6.0*	*6.1*
Urban "combination" VMT (bil.)	N/A	N/A	N/A	9.48	10.8	11.3	11.8	12.6
Change (%)					*4.8*	*4.6*	*4.4*	*6.8*
Total urban truck VMT (bil.)[3]	33.8	39.7	44.7	68.6	72.4	76.3	80.6	85.6
Change (%)		*3.5*	*2.5*	*10.7*	*1.8*	*5.4*	*5.6*	*6.2*
Urban VMT/Total VMT (%)	37.3	36.4	35.5	40.1	40.0	36.9	37.5	37.7
Buses								
Vehicles (000)	195	255	272	323	352	364	379	398
Change (%)		*6.2*	*1.3*	*3.8*	*3.0*	*3.4*	*4.1*	*5.0*
Total VMT (billions)	4.08	4.19	4.35	4.78	4.89	5.04	5.04	5.10
Change (%)		*Neg.*	*Neg.*	*2.0*	*Neg.*	*3.1*	*-0-*	*1.2*
Urban VMT (billions)	1.96	1.79	2.10	2.21	2.24	2.26	2.22	2.20
Change (%)		*-1.7*	*3.4*	*1.0*	*Neg.*	*Neg.*	*-1.8*	*-0.9*
Urban VMT/Total VMT	48.0	42.7	48.3	46.2	45.8	44.8	44.0	43.1

[1]Average annual; [2]Vehicle-miles traveled; [3]May not add because of rounding; [4]Negligible.
Source: Reference 1.

the increase and percentage increase in the number of each of these categories from 1960 to 1970 being:

	Number of vehicles (millions)		Percentage Increase[1]
	1960	1970	
Automobiles	62.3	89.2	43
Cargo vehicles	11.9	18.7	57
Buses	0.3	0.4	39

[1] Calculated before rounding.

Comparable statistics available for 1972 show that automobile registrations grew to 96.9 million, a 4.4 percent increase over 1971 and the number of cargo vehicles and buses rose to 21.6 million, or an increase of 6.9 percent over 1971. The number of all motor vehicles increased to 118.5 million in 1972 from the 1971 level of 113.0 million, an increase of 4.9 percent.

According to Table 1 the greatest growth trend in any single urban category appears to be in the urban vehicle-miles traveled by "single unit" trucks of which there were some 18.8 million in 1971—95 percent of all cargo vehicles and about 18 percent of all motor vehicles. Most of this growth has been in service and local commercial use trucks which do not impinge heavily on peak-hour movement except in unusual cases such as in the garment district and other commercial areas of Manhattan in New York City.

The growth of travel by single unit trucks also attests to the popularity of the recreational vehicle industry which emerged in the mid-60s. The number of vehicles registered in this category may also underestimate the number of such vehicles in use for recreational purposes since in some states single unit trucks may be registered as passenger vehicles for licensing purposes, if it can be proven that no commercial use will be made of the vehicle.

Although single unit trucks represent only about 20 percent of all urban vehicles, their use for recreational purposes, coupled with other recreational vehicles, has been cited as an increasingly important factor in urban congestion due to the impact they have on daily peak-hour volumes (principally the Friday and Sunday afternoon peaks and pre- and post-holiday peaks) and on the directional volumes of traffic. The phenomenal growth of the recreational vehicle industry can be judged by the fact that shipments of new recreational vehicles (travel trailers, truck campers, camping trailers, motorhomes and pickup covers) rose from 80,300 in 1962 to 750,000 in 1972. (2)

Although the increase in the number of motor vehicles owned is a factor in urban congestion, the statistics of greatest interest in this study are the number of miles traveled by these vehicles on urban roadways, the temporal, directional, and spatial distribution of this traffic volume, and the purposes to which the resulting traffic volume can be attributed.

As can be observed from Table 1 the number of vehicle-miles traveled from 1960 to 1970 (summarized below) increased at a much greater rate than the rate of increase in the number of vehicles owned, i.e., more vehicles are traveling much further.

	VMT[1] (billions)		Percentage Increase[2]
	1960	1970	
Automobiles			
Urban	285	495	74
Total	588	891	52
Cargo vehicles			
Urban	45	81	80
Total	126	215	71
Buses			
Urban	2	2	6
Total	4	5	16

[1] Vehicle-miles traveled.
[2] Calculated before rounding

Especially notable is the greater percentage increase in vehicle-miles traveled on urban roadways compared with the increase in total vehicle-miles traveled; the percentage of vehicle-miles traveled on urban roadways being 48 percent in 1960, compared to 56 percent in 1970. In 1972 this percentage was estimated at 54. (3) Naturally, the increase in vehicle-miles traveled on urban roadways does not mean that all of the additional vehicle-miles were shifted to those roadways classified as "urban" in the past. Rather, it is probable that shifts in land-use patterns have caused many previously "rural" roadways to be reclassified as "urban." Irrespective of the cause for the shift, the effect is that a significantly greater percentage of automobile vehicle-miles is now subjected to the characteristics of urban traffic.

The foregoing data on the increasing number of vehicle-miles traveled daily over urban roadways is, of course, one important element of the problem of urban congestion. Of equal or possibly greater significance, however, to the urban congestion problem is the temporal, directional, and spatial distribution of this traffic; in particular, the number of vehicles traveling during peak-traffic hours on major traffic corridors. These travel characteristics are highly dependent on factors such as geography, land-use patterns and the characteristics of the transportation system, which naturally vary widely from urban area to urban area. In general, however, the largest population centers are likely to have the greatest peaking problems. Figure 2 shows the temporal distribution of traffic curve used in the 1972 National Highway Needs Report (4) to portray existing peaking conditions in cities with over one million population. Shown also in Figure 2 is the temporal distribution of traffic in Seattle and Los Angeles. Seattle, with a population far less than Los Angeles, demonstrates peaking characteristics more similar to cities with populations over one million than does Los Angeles. Los Angeles' well-known differences in land-use patterns, developed around the framework of the existing freeway system, exhibits a much more evenly distributed pattern of daily traffic flow than is characteristic for its size.

The most realistic analysis, then, of the impacts of various strategies to reduce congestion by altering the peak-hour traffic volume (discussed in Volume 1, Section 2) would result from an examination of the temporal and directional distribution of traffic on a city-by-city basis. Since it would be outside the scope of this study to make such a detailed examination in order to estimate national impacts, the generalized curve utilized in the 1972 National Highway Needs Report will be used to estimate national impacts. Broadly, this curve indicates that 10-11 percent of the total traffic volume (2-way) will occur in the peak daily travel hour (about 5:00 p.m.) and about 9 percent in the next highest hour (about 8:00 a.m.).

In cities over one million there is virtually no difference in traffic volume from the peak hour to, say, the 200th highest hour of the year, except for

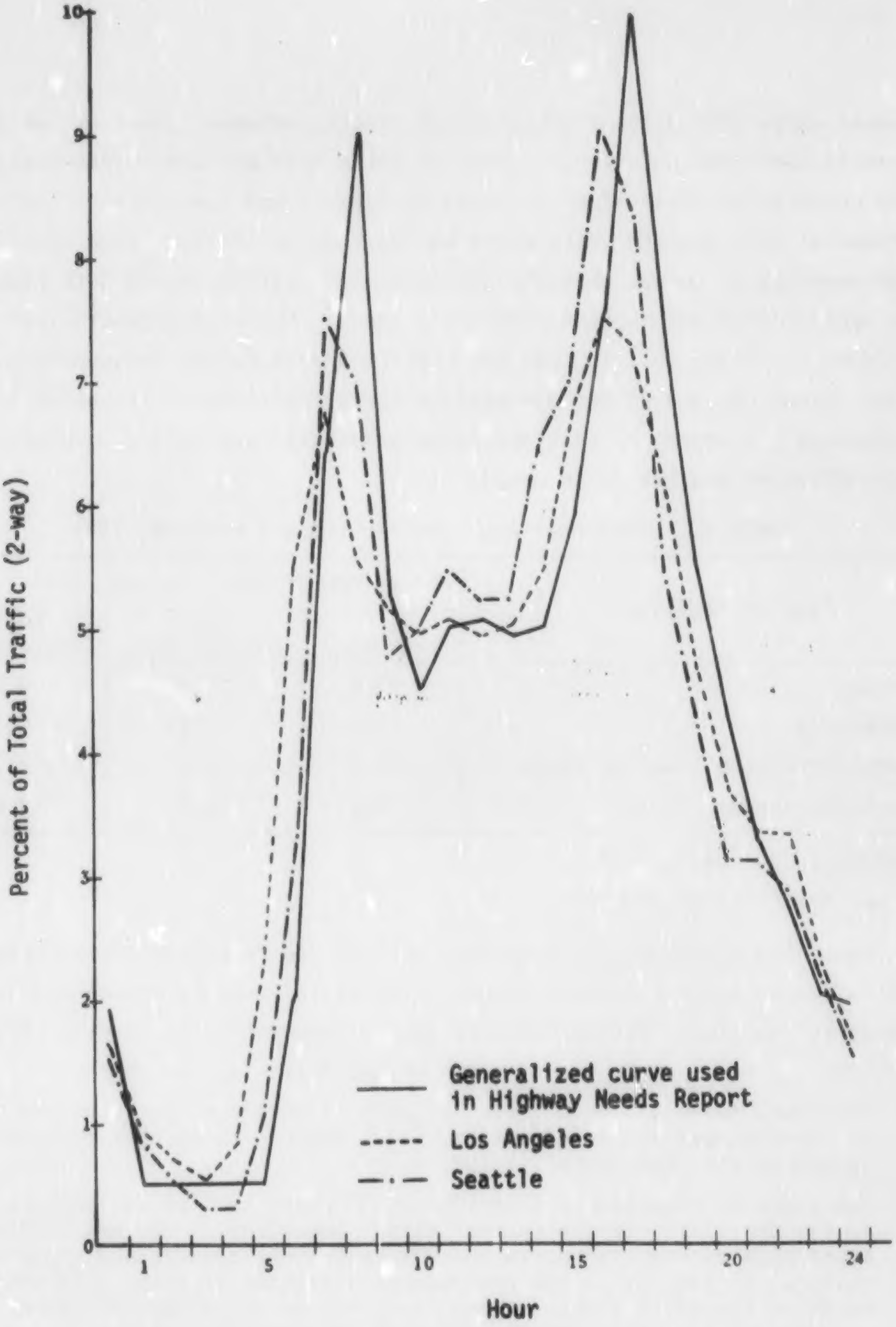

Figure 2. Characteristic temporal traffic distribution curves.

seasonal variations as they affect total traffic volumes. However, data collected in 1960-1961 on a large number of urban roadways and representing a broad spectrum of urban sizes is shown in Table 2 and demonstrates the kind of temporal distribution which might be expected in smaller urban areas. It is interesting to notice that the percentage of traffic in the 30th highest hour approximates the highest peak daily travel hour in the generalized curve of Figure 2. Since this is also the traffic design volume frequently used in highway planning, use of the generalized curve for cities over one million in determining the impact of peak-spreading strategies may tend to overestimate their effect on smaller urban areas.

Table 2. Urban peak-hour traffic characteristics, 1961.

Type of Facility	Percentage of AADT[1] in peak hours, 2-way		
	Peak hour	30th highest hour	200th highest hour
Freeway	13.6	11.0	9.6
Expressway	11.6	9.5	8.3
Street with more than two lanes	12.0	10.0	8.7
Two-lane, two-way street	13.4	10.5	9.0

[1] Average annual daily traffic.

Source: Reference 5, page 40.

Regarding trends in the temporal, spatial and directional distribution of traffic, no evidence of these trends, nationwide, could be documented in the literature reviewed. The opinions of traffic experts in the Federal Highway Administration, however, seemed to agree on the following two points:

1. The trend for urban peak travel volumes is toward a spread of the peak period over longer and longer times, i.e., there is a natural trend toward spreading the peak travel period.
2. The trend in directional distribution of urban traffic is toward a 50:50 split, especially in the central city. According to the Association of State Highway and Transportation Officials (6), traffic now approaches a value of 55 percent in the predominant direction near the city center, while in the outer fringe of the city, values of 65 and 70 percent in the predominant direction still occur with considerable frequency.

Some analysts of urban congestion feel that congestion is self-limiting; being offset, for the most part, by decentralization.* Decentralization does, of course, lead to a more even spatial distribution of traffic and tends to lower and broaden peak travel periods as, for example, in Los Angeles. Other analysts of urban travel habits suggest that changes in travel purposes, especially the trend toward greater social and recreational travel, have been largely responsible for changes in traffic volume characteristics.* To examine this view, recent statistics on the distribution of vehicle-miles traveled and trip length by trip purpose are presented in Table 3 and compared to similar values for the 1951-1958 period.

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*See for example Reference 7, page 299.

A comparison of the values of Table 3 indicates little difference in the distribution of vehicle-miles traveled by trip purpose has occurred over the 15 years between sampling periods. In particular, the distribution of the number of vehicle-miles traveled for social and recreational purposes has, if anything, decreased. The overall social and recreational trip distance, however, has also decreased and, concomitantly, the percentage distribution of trips for this purpose has risen from 17.1 percent in the early period to 22.5 percent in 1969-1970. This trend toward shorter, more frequent, trips at least partially accounts for the increase in weekend traffic volumes which now approach weekday volumes in many urban areas and the high Sunday afternoon-evening traffic peaks.

On balance, it appears that observed urban decentralization has helped to diminish and spread peak traffic volume periods by causing a more even spatial distribution of traffic. Shorter and more frequent social and recreational trips have increased weekend traffic peaks and overall volumes. Conditioning of the urban dweller to the knowledge of peak travel hours has also tended to spread the peak-traffic period, since, to the degree possible, he attempts to schedule his travel to off-peak times.

TRENDS IN THE USE AND AVAILABILITY OF TRANSIT AND PARA-TRANSIT ALTERNATIVES. Public mass transportation reached its peak during World War II and declined rapidly thereafter. This decline was evident in both the number of revenue passengers carried and vehicle-miles operated, as shown in Figures 3 and 4. The resulting changes in the transit industry from 1950 to 1972 are shown in Table 4.

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*See for example Reference 8, pages 3-14.

Table 3. Distribution of vehicle-miles traveled by trip purpose and length.

Purpose of Travel	Percentage distribution, VMT		Average trip distance, two-way, miles	
	1951-58[a]	1969-70[b]	1951-58[a]	1969-70[b]
Earning a living				
To and from work	26.8	34.1	12.8	18.8
Business related to work	16.8	8.0	20.4	32.0
TOTAL	43.6	42.1	14.8	20.4
Family Business				
Medical and dental	1.9	1.6	19.4	16.4
Shopping	7.2	7.6	7.6	8.8
Other	9.9	10.4	13.6	13.0
TOTAL	19.0	19.6	10.7	11.0
Educational, civic, or religious	3.7	5.0	8.2	9.4
Social and recreational				
Vacations	4.9	2.5	592.0	330.2
Visit friends and relatives	c	12.2	c	24.0
Pleasure rides	12.7	3.1	28.4	39.2
Other	16.1	15.5	24.6	22.8
TOTAL	33.7	33.3	29.5	26.2
All purposes	100.0	100.0	15.6	17.8

[a] Source: U.S. Department of Commerce, Bureau of Public Roads, Public Roads. From motor-vehicle-use studies in 22 states 1951-1958.

[b] Source: Preliminary results from the Nationwide Personal Transportation Survey, 1969-1970, Department of Transportation, Federal Highway Administration, Office of Planning.

[c] Category not included.

Of special relevance to this study is the small stock of transit operating equipment currently available and the capacity of the automotive industry to produce new equipment. For instance, in considering the potential impact of increased transit patronage on reducing urban congestion, air pollution and energy use, the availability of equipment and facilities can be a major constraint to the rapid implementation of such offsetting strategies. To illustrate this point, currently there are roughly 50,000 transit buses in operation compared to about 60 million urban automobiles—a ratio of about 1:1200. Assuming that these buses are currently filled to capacity during peak travel hours, should peak-hour transit patronage be doubled, the implication is that 50,000 new buses would have to be placed into operation. The impact of this

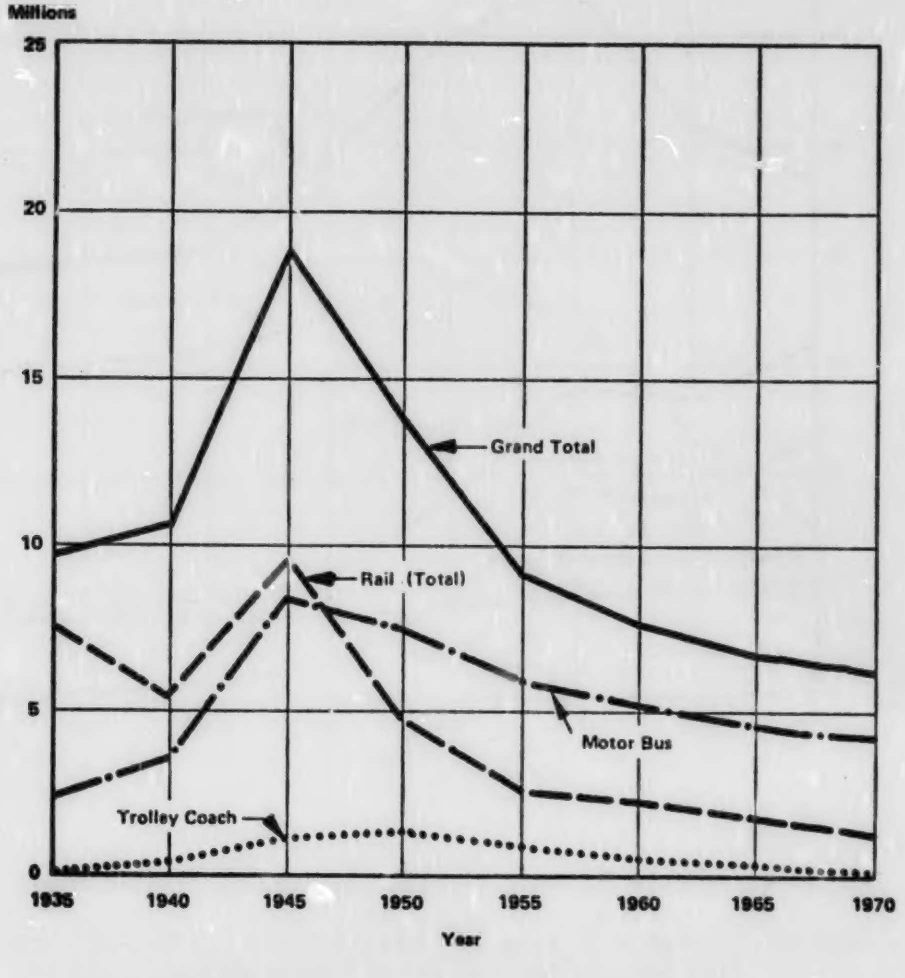

Figure 3. Trends in the number of revenue passengers by transit mode.

Source: Reference 4, page II-3, adapted from "1969-1970 Transit Fact Book," American Transit Association.

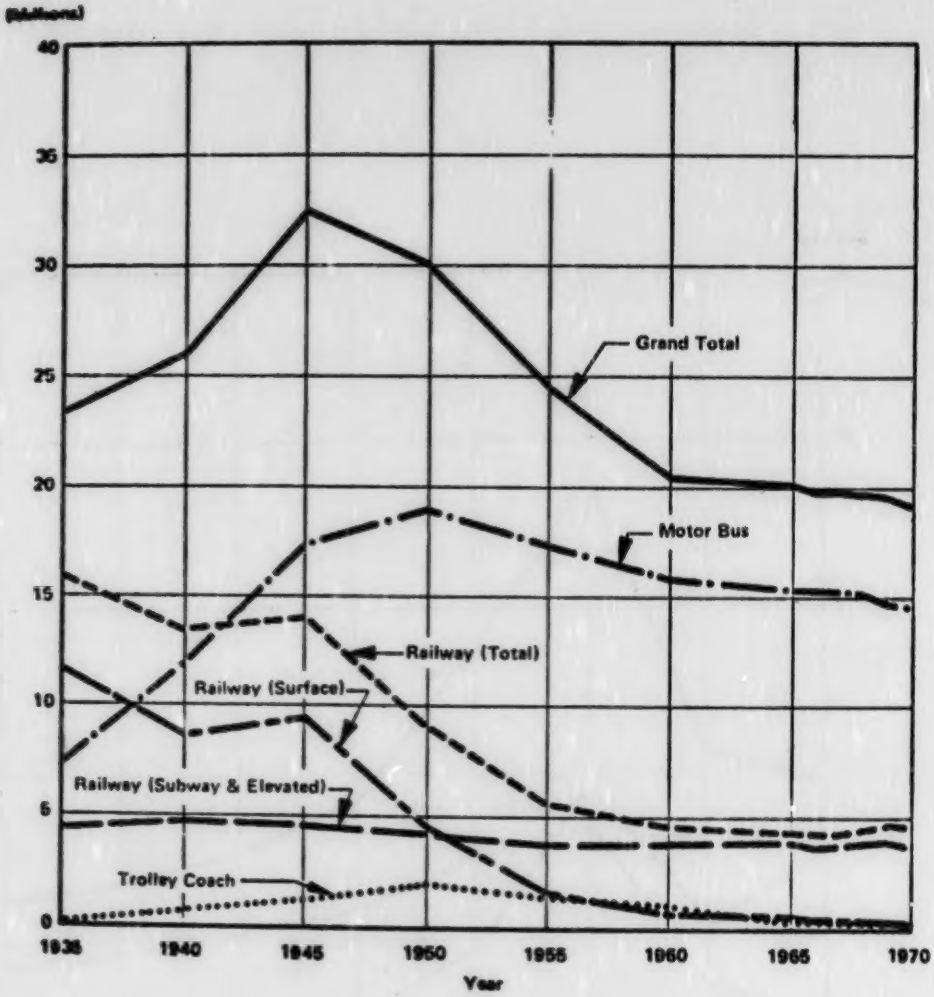

Figure 4. Trends in vehicle-miles operated by transit modes.

Source: Reference 4, page II-2, adapted from "1969-1970 Transit Fact Book," American Transit Association.

Table 4. Changes in the transit industry, 1950-1972.

ITEM	1950	1955	1960	1965	1968	1969	1970	1971	1972 (prel.)
Operating systems	1,406	1,483	1,251	1,148	1,094	1,086	1,079	1,063	1,045
Motorbus systems [1]	1,354	1,450	1,236	1,145	1,091	1,082	1,075	1,059	1,040
Miles of route operated (Dec. 31):									
Electric railway—single track	10,813	6,197	3,935	2,173	2,045	2,081	2,081	(NA)	(NA)
Surface	9,590	4,976	2,692	918	775	762	762	(NA)	(NA)
Subway and elevated	1,223	1,221	1,243	1,255	1,270	1,319	1,319	(NA)	(NA)
Trolley coach—negative overhead wire	3,482	3,428	2,196	766	616	563	563	(NA)	(NA)
Motorbus—route round trip	98,000	99,800	108,700	120,900	121,000	117,300	112,700	(NA)	(NA)
Passenger vehicles owned (Dec. 31)	86,310	73,089	65,292	61,717	61,930	61,347	61,350	60,737	60,704
Electric railway cars	22,986	14,532	11,866	10,664	10,745	10,665	10,600	10,550	10,599
Surface	13,228	5,300	2,856	1,549	1,355	1,322	1,262	1,225	1,176
Subway and elevated	9,758	9,232	9,010	9,115	9,390	9,343	9,338	9,325	9,423
Trolley coaches	6,504	6,157	3,826	1,453	1,185	1,082	1,050	1,037	1,030
Motorbuses	56,820	52,400	49,600	49,600	50,000	49,600	49,700	49,150	49,075
Investment (Dec. 31) mil	3,918	3,821	3,937	4,275	4,533	4,578	4,624	(NA)	(NA)
Electric railway	3,060	2,902	3,003	3,243	3,475	3,502	3,537	(NA)	(NA)
Surface	913	616	367	165	146	145	147	(NA)	(NA)
Subway and elevated	2,147	2,286	2,636	3,078	3,329	3,357	3,391	(NA)	(NA)
Trolley coach	144	160	117	49	38	38	38	(NA)	(NA)
Motorbus	714	759	817	933	1,020	1,038	1,048	(NA)	(NA)
Operating finances:									
Operating revenue	1,452	1,426	1,407	1,444	1,563	1,626	1,707	1,741	1,729
Electric railway	578	440	369	366	411	435	440	428	425
Surface	362	176	88	56	53	55	55	49	48
Subway and elevated	216	264	282	310	358	380	384	379	377
Trolley coach	122	131	82	42	36	33	32	32	31
Motorbus	752	856	956	1,036	1,116	1,158	1,236	1,280	1,271
Operating expenses mil	1,297	1,277	1,290	1,374	1,626	1,745	1,892	2,040	2,128
Percent of revenue	89.3	89.6	91.7	95.2	104.0	107.3	110.8	117.2	123
Net revenue	155	149	117	70	[2] *63*	[2] *119*	[2] *184*	[2] *300*	[2] *400*
Taxes (all)	89	93	87	81	98	101	104	112	113
Operating income	66	56	31	[2] *11*	[2] *161*	[2] *220*	[2] *288*	[2] *411*	[2] *513*
Percent of revenue	4.6	3.9	2.2	(2)	(2)	(2)	(2)	(2)	(2)
Revenue vehicle-miles operated mil	3,008	2,448	2,143	2,008	1,989	1,967	1,883	1,846	1,756
Electric railway	907	561	466	437	444	453	441	440	418
Surface	463	178	75	42	38	36	34	33	32
Subway and elevated	443	383	391	395	407	417	407	407	386
Trolley coach	206	177	101	43	36	36	33	31	30
Motorbus	1,895	1,710	1,576	1,528	1,508	1,478	1,409	1,376	1,308
Passengers carried mil	17,246	11,529	9,395	8,253	8,019	7,803	7,332	6,847	6,567
Electric railway	6,168	3,077	2,313	2,134	2,181	2,229	2,116	2,000	1,918
Surface	3,904	1,207	463	276	253	249	235	222	211
Subway and elevated	2,264	1,870	1,850	1,858	1,928	1,980	1,881	1,778	1,707
Trolley coach	1,658	1,202	657	305	228	199	182	148	144
Motorbus	9,420	7,250	6,425	5,814	5,610	5,375	5,034	4,699	4,505
Revenue passengers carried mil	13,845	9,189	7,521	6,798	6,491	6,310	5,932	5,497	5,271
Electric railway	4,903	2,586	2,005	1,882	1,814	1,840	1,746	1,649	1,581
Surface	2,790	845	335	204	187	184	172	155	148
Subway and elevated	2,113	1,741	1,670	1,678	1,627	1,656	1,574	1,494	1,434
Trolley coach	1,261	869	447	186	152	135	128	113	110
Motorbus	7,681	5,734	5,069	4,730	4,525	4,335	4,058	3,735	3,579
Employees, number (avg) 1,000	240	198	156	145	144	141	138	139	138
Subway and elevated	39	41	35	36	38	37	36	(NA)	(NA)
Surface railway—trolley coach and motorbus	201	157	121	109	106	104	102	(NA)	(NA)
Payroll, employee	835	864	857	964	1,110	1,184	1,274	1,393	1,455
Average annual earnings per employee dollars	3,479	4,364	5,481	6,645	7,727	8,404	9,230	10,014	10,515

NA Not available. [1] Comprises companies operating motorbuses exclusively and companies with combined services such as trolley coach and motorbus, etc. [2] Deficit, not computed as percent of operating revenue.

Source: American Transit Association, Washington, D.C., *Transit Fact Book*, annual.

Reproduced from Statistical Abstract of the United States, 1973, U.S. Department of Commerce, Bureau of the Census, p. 555.

action on urban congestion can be grossly estimated as follows. Assuming the additional transit buses were comfortably full (say, 35 passengers on an average), they could carry some 2 million commuters to work in the morning and bring them home in the evening in a single run each way, or 4 million passenger trips. Using an average two-way commute trip length of 18 miles (see Table 3) some 36 million passenger-miles (now largely served by private vehicles) could be carried daily, if only one round-trip per bus is assumed. Now as shown in Table 1, there were 525 billion urban automobile vehicle-miles traveled in 1971. From Table 3, some 34 percent of these vehicle-miles are likely to be related to travel to and from work—or about 178.5 billion vehicle-miles. Dividing this value by a 250-day work year implies 714 million vehicle-miles per day are now related to commuting to and from work. Assuming an average automobile work-trip occupancy of 1.4 persons per car, the 36 million daily passenger-miles to be carried by the 50,000 buses is the equivalent of about 25.7 million auto vehicle-miles. Therefore, theoretically only about 3-1/2 percent (25.7 ÷ 714) of work-related auto travel demand could be satisfied by doubling the size of the urban bus fleet.* In some areas where work-related travel accounts for the principal volume at peak hours, this might appear to be a partial solution to urban congestion. Unfortunately, however, current domestic productive capacity is limited to about 5,000 new buses annually, and legislation restricts the importation of transit vehicles. Hence, unless productive capacity is increased by providing convincing evidence to the automotive industry of a sustained increase in demand, and/or legislation is altered, 10 years would be required to implement this strategy.

It should not be inferred from this discussion that increasing transit (bus) patronage is not a potentially viable strategy to reduce urban congestion, air pollution, and petroleum consumption, but rather that the payoffs from this strategy can not be realized in the short term unless significant ancillary actions are taken. One of these actions (in addition to increasing the productive capacity of the automotive industry and/or possibly altering legislation) would, of course, be the complementary action required to increase the utilization of transit buses during offpeak travel periods.

There are also many instances where an individual bottleneck, such as a bridge or a major intersection, is responsible for congested conditions throughout a larger portion of the network. Bus transit circumventing such bottlenecks can often divert enough travel demand to relieve congestion. In such cases, the use of bus transit would have a greater local impact on congestion than implied by the above overall analysis.

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*A more comprehensive exercise of this kind which considers the practical limits of an auto-bus shift is performed in Volume 2, Section 2.

Contrary to the decline in the transit industry documented above, the para-transit industry has shown some increase in patronage and use over this same period. The increase in the number of taxicabs in service and revenue vehicle-miles carried by them, for example, is documented in Table 5.

Table 5. Changes in the taxicab industry, 1960-1970.

Item	1960	1965	1970	Percent Change 1960-70
Number of vehicles (000)	130	140	175	35
Revenue vehicle-miles (mil)[1]	5,200		6,800	31

[1] As reported in the below source. Other sources (i.e., Wells, John D. et al (Institute for Defense Analyses), Economic Characteristics of the Urban Public Transportation Industry, prepared for U.S. DOT, February 1972, p. 8-6; and Husted, Robert, "Mass Transit Impact on Energy Consumption," Society of Automotive Engineers Report No. 730521, 1973) indicate that the value is actually total vehicle-miles.

Source: Reference 10, p. 78.

Some idea of the comparative utilization of taxis and transit buses can be gained by considering that if the average number of passengers carried by taxis were 1.3, and 50 percent of the vehicle-miles were revenue bearing (11), then some 4,420 million passenger-miles (6,800 × .5 × 1.3) would have been traveled by taxi in 1970. Using a liberal average loading factor of 25 passengers for buses and a value of 1,409 million revenue motorbus vehicle-miles traveled in 1970 (Table 4), some 35,225 passenger-miles (1,409 × 25) would have been traveled by bus. Thus, taxis were responsible for about one-eighth as many passenger-miles in 1970 as buses.

While para-transit vehicles unquestionably help to alleviate urban congestion, these vehicles, by and large, still have internal combustion engines which consume petroleum and add to air pollution. Therefore, the increasing trend toward para-transit modes is examined in Volumes 1 and 2 to determine their potential contribution to these problems.

TRENDS IN THE EXTENSION OF THE ROADWAY SYSTEM. The major countermeasure against the congestion created by the trends toward greater numbers of urban motor vehicles traveling increasing distances and the general decline of the transit industry has been the extension of the roadway system. The magnitude of this undertaking can be judged by noting that in 1921 there were a total of 450,000 miles of surfaced roadways in the U.S.; in 1971 this figure had grown to some 3,760,000 miles—the equivalent of adding over 65,000 miles of new surfaced roadway to the roadway system in each of the 50 years. Of the total mileage, some 600,000 miles are now in municipalities, a ratio of one urban mile to about five rural miles. (The ratio of municipal lane-miles to rural lane-miles is also approximately 1:5.) (3)

The total cost for this expansion of the roadway system from 1952 through 1972 was as shown in Table 6. Referring to this table, if the urban cost for administration and research, law enforcement and safety, interest on debt and debt retirement bears the same relationship to the total cost for these items (i.e., 30 percent) as the urban cost for maintenance and operation, then the "all other" category for municipal systems would be about $27 billion, or an average annual amount of about $1.3 billion. Comparing the investment in rural and municipal systems, then, reveals the following:

	Costs, 1952-1972 (Billion 1972 dollars)	
	Total	Average Annual
Rural systems	247	11.7
Municipal systems	127	6.1
TOTAL	374	17.8

Therefore, although the ratio of municipal to rural lane-mileage is about 1:5, the ratio of municipal to rural highway investment has been about 1:2 over the time period examined. This latter ratio is, of course, more in line with the municipal to rural ratio of vehicle-miles traveled

Table 6. Costs of municipal and rural roadway system, 1952-1972.

Roadway System/Category	Costs (Million, 1972 dollars)	
	Total	Average Annual
Municipal and Rural System		
Capital outlay for construction[1]	193,461	9,212
Maintenance and operation[2]	89,330	4,254
All other[3]	91,288	4,347
TOTAL	374,079	17,813
Municipal System Only[5]		
Capital outlay for construction[1], [6]	73,057	3,479
Maintenance and operation[2]	27,192	1,295
All other[4], [7]	--	--
TOTAL	100,249	4,774

[1] Costs adjusted to constant 1972 dollars according to "Price Trends for Federal-Aid Highway Construction," Office of Highway Operations, FHWA.
[2] Costs adjusted to constant 1972 dollars according to "Cost Trends, Highway Maintenance and Operations," Office of Highway Operations, FHWA.
[3] Includes administration and research, highway law enforcement and safety, interest on debt, debt retirement and cost of rights-of-way.
[4] Costs adjusted to 1972 dollars using the GNP implicit price deflator.
[5] 1951-1971.
[6] Includes right-of-way.
[7] Municipal/rural breakdown is not available.

Source: Reference 1.

of about 1:1. The effectiveness of these investments can be at least partially judged by the current status of urban congestion examined below.

Current Status of Urban Traffic Congestion. Since urban traffic congestion varies markedly at different locations on each roadway and with time, the best assessment of the severity of urban congestion, nationwide, would be one based on an aggregation of congestion indexes from segments of all individual urban roadways. Considering that in 1971 there were some 600,000 miles of roadways in urban areas in the United States, such a task would be insurmountable. However, based on representative sample data, this approach was used in the 1972 National Highway Needs Report (4) to estimate the existing need for improved and new urban roadways and in forecasting future urban highway needs. Since the results of this work are recent and authoritative, they are summarized and presented here as the best available measure of existing urban traffic congestion on a nationwide basis.

The measures of congestion used to establish the need for additional capacity on urban arterials in the 1972 National Highway Needs Report* are (1) the actual peak-hour operating speeds (used for freeways and expressways) and (2) the volume/capacity ratio (used for surface arterials). Each of these measures is related to five levels of service as shown in Tables 7 and 8. (5**)

Table 7. Levels of service for freeways and expressways.

LEVEL OF SERVICE	TRAFFIC FLOW CONDITIONS		SERVICE VOLUME/CAPACITY (v/c) RATIO[d]				
	DESCRIPTION	OPERATING SPEED[a] (MPH)	BASIC LIMITING VALUE FOR AVERAGE HIGHWAY SPEED (AHS) OF 70 MPH, FOR:			APPROXIMATE WORKING VALUE FOR ANY NUMBER OF LANES FOR RESTRICTED AVERAGE HIGHWAY SPEED OF	
			4-LANE FREEWAY (2 LANES/ DIRECTION)	6-LANE FREEWAY (3 LANES/ DIRECTION)	8-LANE FREEWAY (4 LANES/ DIRECTION)	60 MPH	50 MPH
A	Free flow	⋝60	⋜0.35	⋜0.40	⋜0.43	—[b]	—[b]
B	Stable flow (upper speed range)	⋝55	⋜0.50	⋜0.58	⋜0.63	⋜0.25	—[b]
C	Stable flow	⋝50	⋜0.75×PHF[c]	⋜0.80×PHF	⋜0.83×PHF	⋜0.45×PHF	—[b]
D	Approaching unstable flow	⋝40	⋜0.90×PHF			⋜0.80×PHF	⋜0.45×PHF
E[d]	Unstable flow	30-35[e]	⋜1.00				
F	Forced flow	<30[e]	← Not meaningful →				

[a] Operating speed and basic v/c ratio are independent measures of level of service, both limits must be satisfied in any determination of level.
[b] Operating speed required for this level is not attainable even at low volumes.
[c] PHF is peak-hour factor.
[d] Capacity.
[e] Approximately.

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*Part II, p. IV-65.
**Excerpted from Tables 9.1 and 10.13

Table 8. Levels of service for urban and suburban arterials.

LEVEL OF SERVICE	TRAFFIC FLOW CONDITIONS (TYPICAL APPROXIMATIONS, NOT RIGID CRITERIA)				SERVICE VOLUME/ CAPACITY RATIO[a,c]
	DESCRIPTION	AVERAGE[a] OVERALL TRAVEL SPEED (MPH)	LOAD[a] FACTOR	LIKELY PEAK-HOUR FACTOR[b]	
A	Free flow (relatively)	≥30	0.0	≤0.70	≤0.60 (0.80)
B	Stable flow (slight delay)	≥25	≤0.1	≤0.80	≤0.70 (0.85)
C	Stable flow (acceptable delay)	≥20	≤0.3	≤0.85	≤0.80 (0.90)
D	Approaching unstable flow (tolerable delay)	≥15	≤0.7	≤0.90	≤0.90 (0.95)
E[d]	Unstable flow (congestion; intolerable delay)	Approx. 15	≤1.0 (0.85 typical)[e]	≤0.95	≤1.00
F	Forced flow (jammed)	<15	(Not meaningful)	(Not meaningful)	(Not meaningful)[f]

[a] Operating speed and v/c ratio are independent measures of level of service; both limits should be satisfied in any determination of levels, with due consideration given to the fact that they are largely rationalizations. Load factor, a measure of individual intersection level of service, can be used as a supplemental criterion where necessary.

[b] This is the peak-hour factor commonly associated with the specified conditions; in practice, considerable variation is possible.

[c] Values in parenthesis refer to near-perfect progression.

[d] Capacity.

[e] Load factor of 1.0 is infrequently found, even under capacity operation, due to inherent fluctuations in traffic flow.

[f] Demand volume/capacity ratio may well exceed 1.00, indicating overloading.

For purposes of establishing urban highway needs, a service level of D is considered the minimum service acceptable for freeways and expressways in larger urban areas (i.e., an operating speed of 40 mph or greater) and a service level of about E in small urban areas (35 mph or greater). For major urban surface arterials, a service level which results in a service volume/capacity ratio greater than 0.85 is considered "intolerable" (i.e., a level of service which approaches unstable flow [D] is considered tolerable) in both large and small urban areas; for minor arterials a volume/capacity ratio greater than 0.95 is considered intolerable (i.e., level of service E).

Based on measurements made of actual peak-hour operating speeds on urban freeways and expressways and traffic volumes on urban surface arterials with rated capacities, the percentage distribution of existing mileage with respect to these characteristics at peak hours is as shown in Table 9.

Table 9. Nationwide percentage distribution of existing (1972) roadway mileage on urban arterials (other than the Interstate) by peak-hour operating speed or peak-hour capacity ratio.

Type of Area and Population Group	Freeways and Expressways						Principal Arterials Other Than Freeways and Expressways							Minor Arterials						
	Peak Hour Operating Speed (mph)						Present peak hour volume/capacity ratio							Present peak hour volume/capacity ratio						
							Intolerable			Tolerable				Intolerable		Tolerable				
	<35	35-39	40-44	45-49	50-54	>54	>0.95	0.91-0.95	0.86-0.90	0.75-0.85	0.50-0.74	0.25-0.49	<0.25	>0.95	0.91-9.95	0.86-0.90	0.75-0.85	0.50-0.74	0.25-0.49	<0.25
Small Urban																				
5,000- 10,000	23	3	3	3	6	62	5	1	1	3	14	34	42	2	*	*	2	6	21	69
10,000- 25,000	18	2	3	6	3	68	8	1	1	4	15	34	37	2	*	1	1	8	21	67
25,000- 50,000	17	4	3	7	6	63	9	2	2	5	18	33	31	5	*	1	3	10	24	57
Total small urban	18	3	3	6	5	65	7	1	1	4	16	34	37	3	*	1	2	8	22	64
Total built-up areas	18	5	2	5	6	64	11	1	2	6	21	34	25	7	1	1	4	14	30	43
Total outlying areas	19	2	3	6	4	66	4	1	1	3	11	34	46	2	*	*	1	6	19	72
Urbanized																				
50,000-100,000	18	3	10	10	11	48	12	1	2	5	17	32	31	4	1	1	2	10	24	58
100,000-250,000	6	3	3	9	12	67	14	2	2	7	20	30	25	6	1	1	3	13	25	51
250,000-500,000	27	5	2	8	7	51	16	2	2	5	20	31	24	7	*	1	3	13	26	50
500,000-1,000,000	11	1	6	6	8	68	19	2	3	8	22	27	19	11	1	1	4	14	26	43
>1,000,000	18	4	11	14	16	37	22	3	3	7	22	25	18	11	1	2	5	16	27	38
Total urbanized	16	4	9	12	14	45	19	1	3	7	21	28	21	10	1	1	4	15	26	43
Total built-up areas	21	5	11	17	12	34	27	3	3	8	24	23	12	15	1	2	7	20	28	27
Total outlying areas	14	3	7	9	15	52	12	2	2	5	18	31	30	7	1	1	3	13	25	50

*Less than 0.5%

Source: Compiled from Reference 4, Part II, Tables IV-22 and IV-23.

Summarizing Table 9, the following percentages of the urban roadways considered are not providing acceptable levels of service:

	Urban roadways with unacceptable service levels (%)		
	Freeways	Principal surface arterials	Minor arterials
Small urban areas	18	9	3
Urbanized areas	20	23	11

If these percentages are applied to the mileage existing in 1970 in each of the categories (4), 19 percent of all major urban roadway mileage (freeways and principal surface arterials, but excluding the urban portion of the Interstate system) is congested at peak-hour travel times. The reduced congestion on minor arterials, in conjunction with their greater mileage, drops this estimate to some 14 percent if all three categories are included.

The fact that less than 20 percent of the roadway mileage on major urban arterials in the U.S. is congested for only a few hours on some days attests to the skill of highway designers and planners in keeping up with increases in vehicular use (accelerated by the decrease in the availability of mass transit alternatives) and changes in land use patterns. However, even though the number of miles of roadways currently congested at peak travel periods is a relatively small percentage of the total mileage, the number of individuals inconvenienced daily on congested sections is considered to be unacceptable in terms of the economic and social losses suffered as a result of congestion. Future trends in urban travel will now be examined in order to gain an insight into the probable future highway investments which will be required to maintain urban traffic flows at least at their current level. These values will also provide a quantitative basis for comparing the costs of alternative strategies.

Future Trends

After a review of the relevant literature, it was concluded that possibly the most informed and balanced portrayal of future trends re-

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lated to urban congestion was contained in the 1972 National Highway Needs Report. The base travel forecast used in this work is reproduced in Table 10. Table 11 summarizes the highway mileage figures and presents annual figures for vehicle-miles traveled calculated from the daily figures in Table 10.

Table 10. Comparison of 1968 miles of highway and daily vehicle-miles of travel on functional systems with the estimates for 1990.

Area and functional systems	Miles of highways							Daily vehicle-miles of travel (thousands)						
	1968			1990			Percent change 1968-1990	1968			1990			Percent change 1968-1990
	Number	Percent of-		Number	Percent of-			Number	Percent of-		Number	Percent of-		
		Area miles	Total miles		Area miles	Total miles			Area travel	Total travel		Area travel	Total travel	
Rural														
Principal arterial systems:														
Interstate	22,359	0.7	0.6	31,552	1.0	0.8	41	182,057	13.7	6.5	516,106	25.4	10.1	184
Other	90,559	3.0	2.6	82,055	2.7	2.1	-9	341,681	25.7	12.3	479,376	23.6	9.4	40
Total	112,918	3.7	3.2	114,607	3.7	2.9	1	523,738	39.4	18.8	995,482	49.0	19.5	
Minor arterial system	169,061	5.5	4.7	177,603	5.7	4.5	5	298,032	22.5	10.7	436,121	21.4	8.6	46
Total arterial systems	281,979	9.2	7.9	292,210	9.4	7.4	4	821,770	61.9	29.5	1,431,803	70.4	28.1	74
Collector systems:														
Major	265,321	8.6	7.5	276,571	8.9	7.1	4	199,009	15.0	7.1	280,134	13.8	5.5	41
Minor	425,500	13.8	11.9	433,180	13.9	11.0	2	118,872	8.9	4.3	139,496	6.9	2.7	17
Total	690,821	22.4	19.4	709,751	22.8	18.1	3	317,881	23.9	11.4	419,630	20.7	8.2	32
Local system	2,106,814	68.4	59.0	2,105,228	67.8	53.7	-0.1	189,375	14.2	6.8	180,012	8.9	3.5	-5
Total all systems	3,079,614	100.0	86.3	3,107,189	100.0	79.2	0.9	1,329,026	100.0	47.7	2,031,445	100.0	39.8	53
Urban														
Small urban areas														
Principal arterial systems:														
Freeways and expressways:														
Interstate	499	0.4	1/	1,102	0.7	1/	121	5,585	2.7	0.2	23,464	7.5	0.5	320
Other	633	0.5	1/	2,034	1.2	1/	221	6,609	3.2	0.2	26,132	8.4	0.5	295
Total	1,132	0.9	1/	3,136	1.9	1/	177	12,194	5.9	0.4	49,596	15.9	1.0	307
Other principal	12,121	9.5	0.4	14,265	8.4	0.4	18	89,802	43.8	3.2	120,000	38.4	2.3	34
Total	13,253	10.4	0.4	17,401	10.3	0.4	31	101,996	49.7	3.6	169,596	54.3	3.3	66
Minor arterial system	11,708	9.2	0.3	17,444	10.3	0.5	49	38,246	18.7	1.4	63,624	20.3	1.1	66
Total arterial systems	26,961	19.6	0.7	36,865	20.6	0.9	40	140,242	68.4	5.0	233,220	74.6	4.6	66
Collector system	13,135	10.3	0.4	17,362	10.2	0.4	32	20,141	9.8	0.7	28,995	9.3	0.5	44
Local systems	89,331	70.1	2.5	117,298	69.2	2.0	31	44,829	21.8	1.6	50,214	16.1	1.0	12
Total all systems	127,447	100.0	3.6	169,505	100.0	4.3	33	205,232	100.0	7.3	312,429	100.0	6.1	52
Urbanized areas:														
Principal arterial systems:														
Freeways and expressways:														
Interstate	4,596	1.3	0.1	9,996	1.5	0.3	118	181,766	14.5	6.5	555,260	20.1	10.9	206
Other	3,437	0.9	0.1	16,380	2.5	0.4	377	116,975	9.3	4.2	620,725	22.5	12.2	431
Total	8,031	2.2	0.2	26,376	4.0	0.7	228	298,741	23.8	10.7	1,175,985	42.6	23.1	294
Other principal	26,414	7.3	0.8	37,376	5.8	0.9	42	390,284	31.2	14.0	569,622	20.6	11.1	46
Total	34,445	9.5	1.0	63,750	9.8	1.6	85	689,025	55.0	24.7	1,745,607	63.2	34.2	153
Minor arterial system	35,283	9.7	1.0	67,365	10.4	1.7	91	254,705	20.3	9.2	501,526	18.2	9.8	97
Total arterial systems	69,728	19.2	2.0	131,045	20.2	3.3	88	943,730	75.3	33.9	2,247,131	81.6	44.0	138
Collector system	30,818	8.5	0.8	57,267	8.9	1.5	86	96,965	7.7	3.5	197,958	7.2	3.9	104
Local system	261,965	72.3	7.3	458,707	70.9	11.7	75	213,020	17.0	7.6	313,761	11.4	6.2	47
Total all systems	362,511	100.0	10.1	647,049	100.0	16.5	79	1,253,715	100.0	45.0	2,758,850	100.0	54.1	120
Total rural and urban	3,569,572		100.0	3,923,763		100.0	10	2,787,973		100.0	5,102,776		100.0	83

1/ Less than 0.05 percent.

Source: Reference 4, Part II, Table III-4.

This forecast was prepared by the state highway departments in cooperation with the Federal Highway Administration for the "National Highway Functional Classification and Needs Study, 1970-1990." It is unconstrained with

Table 11. Miles of roads and streets in service and annual vehicle-miles of travel: 1968 actual and 1990 as forecasted.

	1968	1990	Change
Mileage			
Rural	3,079,614	3,107,189	27,575
Urban	489,958	816,574	326,616
TOTAL	3,569,572	3,923,763	354,191
Vehicle-Miles (millions)			
Rural	485,093	741,477	256,384
Urban	532,514	1,121,017	588,503
TOTAL	1,017,607	1,862,494	844,887

respect to the major offsetting phenomena considered in this study (i.e., impacts on travel demand of air pollution legislation or limiting energy usage) or changes in existing public policies. The base projection does, however, include the assumption that the 4.2 percent per year growth in vehicle-miles traveled experienced from 1950-1970 will be slightly slowed over the next 20 years, and that a slight increase in transit ridership will take place (a linear increase from the 1968 value of 8 billion trips to a 1990 value of 10.1 billion trips per year). The degree to which the base projection varies from past trends in these two travel characteristics is shown in Figures 5 and 6.

The cost required to expand the highway system to meet the projected demand is, however, estimated in the above-referenced study only for the federal-aid highway system. Therefore, to obtain some idea of the magnitude of expenditures implied for the total forecast extensions, and also to provide some way of assessing the economic impact of offsetting strategies to be examined in the subsequent analysis, the incremental investment per incremental vehicle-mile was calculated, based on historical expenditure records from 1950. The details of these calculations are presented in Appendix C. Broadly, annual expenditures were tabulated in the three categories listed in Table 6: construction, maintenance and operation, and "all other" which included expenses for administration and research, law enforcement and safety, interest on debt, debt retirement and rights-

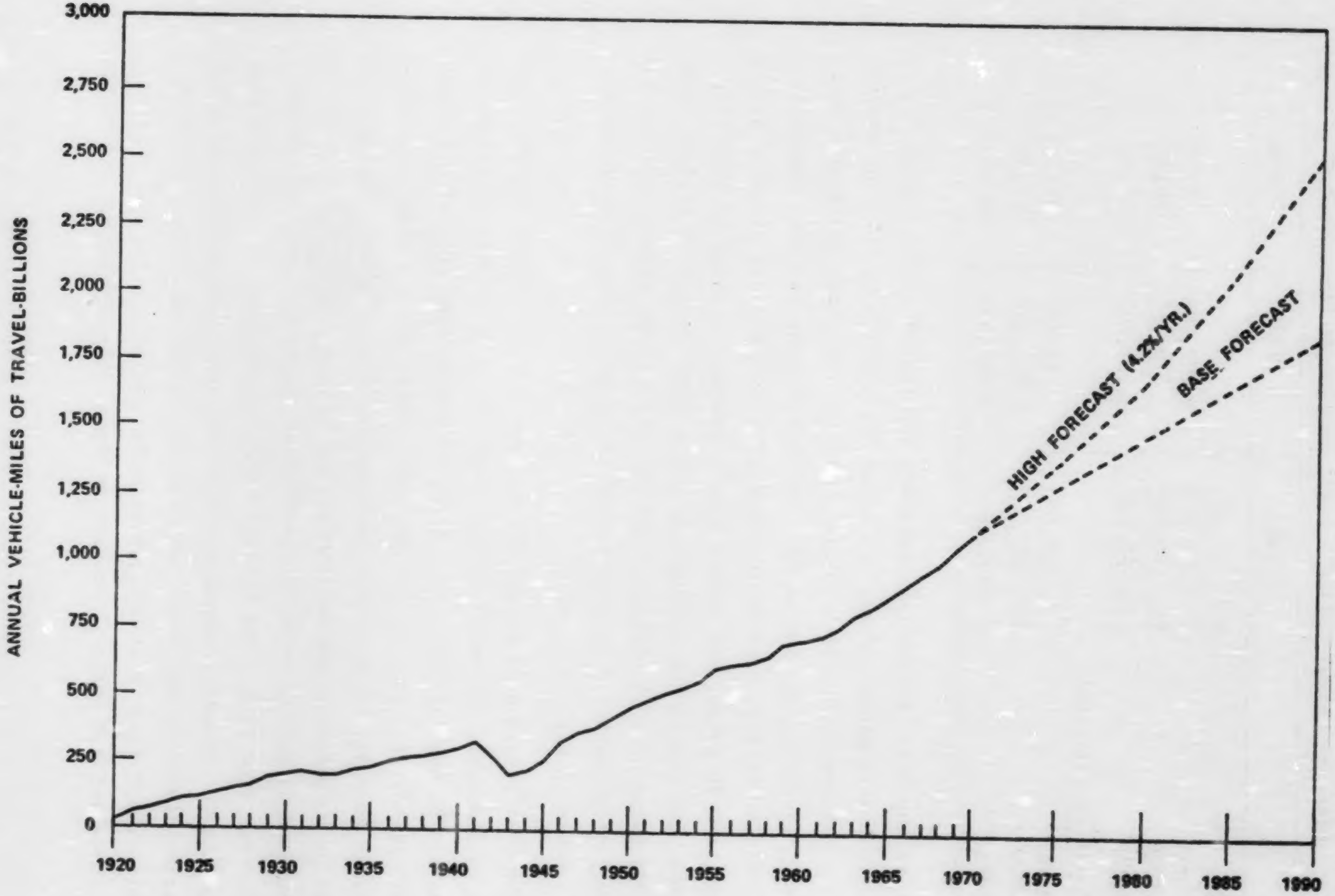

Figure 5. Trend and forecasts of national travel.

Source: Reference 4, Part II, Figure II-12.

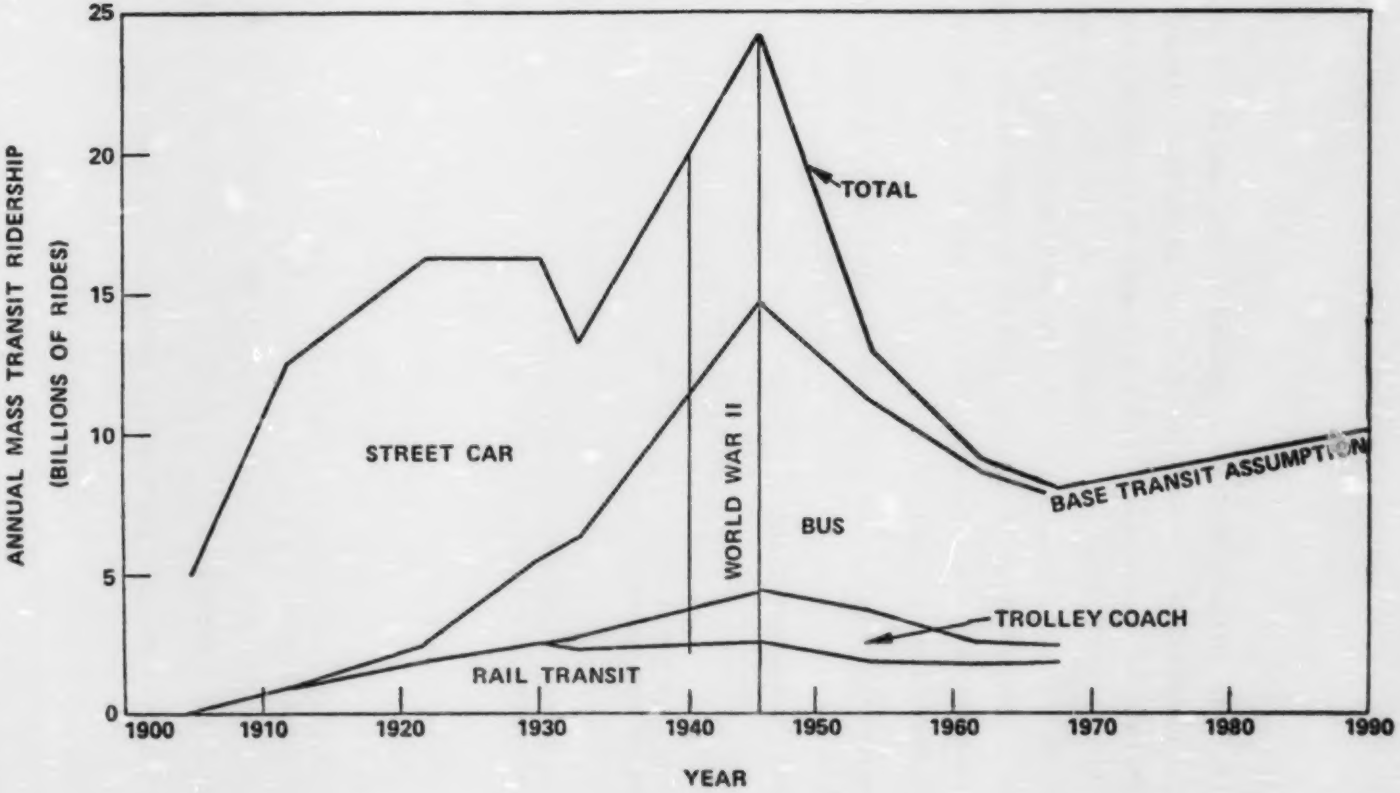

Figure 6. Urban transit patronage trends and base forecast.

Source: Reference 4, Part II, Figure II-19.

of-way. Appropriate indices were then applied to the annual amounts in each category to convert all amounts to 1972 dollar values. Annual increments or decrements of change in expenditures were then calculated and averaged over the 1950-1972 time period examined. By dividing the average annual change in all expenditures (in constant 1972 dollars) by the average annual change in vehicle-miles traveled, a gross measure of the incremental cost per incremental vehicle-mile was obtained. The results of these calculations are summarized in Table 12.

Table 12. Incremental expenditures per incremental vehicle-mile, 1950-1972.

Average Annual Change (millions):	
Municipal and Rural	
Capital outlay (excluding right-of-way)	$313
Maintenance and operations	81
Subtotal	394
Administration, right-of-way, law enforcement, debt retirement and interest on debt	222
TOTAL	$616
Vehicle-miles traveled	33,807
Municipal	
Capital outlay (including right-of-way)	$163
Maintenance and operations	40
TOTAL	$203
Vehicle-miles traveled	18,797

Incremental Expenditures per Incremental Vehicle-Mile Traveled:

$$\frac{\$616}{33{,}807} = \$0.018$$

Each additional vehicle-mile traveled, then, corresponded, on an average, to an additional 1.8¢ in highway expenditures (1972 dollar value) over the period examined.* Average annual incremental municipal expenditures and vehicle-miles traveled are also shown in Table 12 in those categories where these records were available. Although right-of-way expenditures (10-15 percent of total capital outlay expenses) are not isolated by municipal and rural categories, the ratio of municipal incremental expenditures to incremental vehicle-miles traveled is surprisingly almost identical to the rural ratio for the comparable categories. That is:

$$\text{(Municipal) } \frac{\$203}{18{,}797} = \$0.011; \text{ and (Rural) } \frac{\$394 - 203}{33{,}807 - 18{,}797} = \$0.013.$$

The equivalent incremental cost for municipal and rural vehicle-miles arises because the average annual incremental change in expenditures for both categories is nearly the same, as is the average annual increase in vehicle-miles. Total expenditures for the rural highway system are, of course, approximately twice the municipal expenditures.

Applying this incremental cost, then, to the total projected increase in vehicle-miles to 1990 according to the estimates of Tables 10 and 11, the average annual increment in vehicle-miles becomes 38,404 million vehicle-miles per year (844,887 million ÷ 22). Assuming that average annual "base" expenditures to maintain the current system are, say, $20 billion (see Table 6), total "base" expenditures for 1968-1990 become $440 billion (22 x 20). If annual incremental expenditure for roadway expansion is $0.018 per additional vehicle-mile, the total annual amount will be about $700 million annually (38,404 x 0.018). Total incremental expenditures can then be calculated as follows:

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*It is recognized that all of the expenditure increments (or decrements) in one year might not be considered as directly caused by the additional vehicle-miles traveled in that year, e.g., construction required to meet new design standards for, say, safety,or debt retirement. However, considering the length of the time period examined and the fact that all increments are averaged over this period, it is felt that the results obtained are sufficiently valid to be used as a basis for obtaining a *grosso modo* estimate of probable future expenditures, if no major changes in public policy transpire or other offsetting phenomena occur.

$$
\begin{aligned}
x_1 &= 20{,}000 \\
x_2 &= 20{,}000 + 700 \\
x_3 &= 20{,}000 + 700 + 700 \\
&\vdots \\
x_{22} &= 20{,}000 + (700)\ (21)
\end{aligned}
$$

where x_1 = total estimated expenditures (millions) in year 1; x_2 = total estimated expenditure (millions) in year 2; etc. The result is an estimate of total expenditures due to projected increases in total vehicle-miles traveled from 1968-1990 of about $160 billion, and a total estimated outlay of $600 billion for this period. For a 20-year period, estimated expenditures for increases in vehicle-miles are $133 billion and "base" expenditures are $400 billion, or a total projected investment of $533 billion. For this sum, in the 20th year some 768 billion additional vehicle-miles of travel will have been accommodated on roadways annually with approximately the same degree of congestion as now exists.

Applying these calculations to urban systems, the projected average annual increase in urban travel is 26,750 million vehicle-miles (588,503 ÷ 22). The annual incremental expenditure becomes $482 million (26,750 × 0.018) and the estimated expenditures for vehicle-mile increases over 20 years amount to $92 billion. Assuming "base" expenditures of $6 billion, the total "base" expenditure for the 20 years is $120 billion—a total anticipated expenditure of $212 billion on urban roadways over the next 20-year period to accommodate current traffic and anticipated increases in vehicle-miles amounting to 535 billion vehicle-miles.

If these calculations are performed for a 20-year period, based only on urban construction and right-of-way investments (see Table 12), an incremental cost of $0.0087 ($163 million ÷ 18,797 million vehicle-miles), or 87 mills, is implied. Average annual incremental investment costs for the anticipated average annual increase in urban travel of 26,750 million vehicle-miles becomes $233 million (26,750 × 0.0087). Total incremental expense for the 20-year period then amounts to some $45 billion. The value of $45 billion represents estimated roadway investments solely for new construction and rights-of-way which would be required over the next 20 years in urban areas to accommodate the estimated increases in motor vehicle travel of 535 billion vehicle-miles. Broadly, this amount also is comparable to investments which might be made on alternative transit systems.

TRANSPORTATION-RELATED AIR POLLUTION

Although the problem of urban air pollution has existed in various forms throughout U.S. history, only fairly recently has national concern been great enough to cause federal attention to be focused on it. As a result, and contrary to the situation vis-à-vis the problems of urban congestion and energy consumption, little or no historical statistical data exists from which past trends can be deduced. In this instance the absence of past trends is of little consequence, however, since in view of the significant existing regulatory legislation, future trends in air pollution will be based on the degree to which these regulations will offset the existing status and the time of their implementation, rather than on the extrapolation of past trends.

However, regarding air pollution legislation and resulting regulations, INTERPLAN's review of the relevant literature revealed that the statistics quoted by various sources at times appeared contradictory, both with regard to the air quality standards and their interpretation and motor vehicle emission controls, and with regard to the effect of these controls on the estimated levels of pollutants which would be emitted under various assumptions. Much of this confusion has resulted from the numerous changes which have been made in the scheduled implementation dates for various regulations. Thus, as a preface to the subsequent presentation of the current status of air pollution and future trends, a brief historical summary of air pollution legislation and the resulting regulations and their implementation schedules is given below.

Summary of Past Air Pollution Legislation and Regulations

Table 13 lists the significant events in air pollution legislation from 1959 through 1974 and their results, with special emphasis on motor vehicle emission regulations* and scheduled implementation dates.

Ambient Air Quality and Motor Vehicle Emission Standards

Two sets of regulatory standards have emerged from the events documented in Table 13: the National Ambient Air Quality Standards and the Federal Motor Vehicle Emission Standards. The National Ambient Air Quality Standards are shown in Table 14. Table 15 summarizes the current status of the Federal Motor Vehicle Emission Standards for light-duty vehicles.

The determination of each of these sets of standards has been interpreted as a separate obligation arising from the 1970 amendments to the Clean Air Act (15); the auto emission control regulations were, in fact, stipulated before the ambient air quality standards were established, as shown in Table 13, and were not derived from them although, of course, the resultant effects are related. In effect, the auto emission standards were derived by determining the existing levels of emissions in 1970 or 1971 and then simply requiring a 90 percent reduction in these levels. In contrast, the air quality standards were based on the results of tests which aimed to determine the levels of major air pollutants which would affect the public health (expressed in the primary standards) and the public welfare (expressed in the secondary standards). The scientific basis for the resulting air quality standards is set forth in several volumes of air quality criteria, one each for sulfur oxides, carbon monoxide, photochemical oxidants, particulate matter, nitrogen oxides, and hydrocarbons (17-22). The data bases for the health effects of these pollutants are subject to review and updating. It is an EPA goal for fiscal year 1974, for example, to update the health effects data in support of the standards for CO, NO_x, SO_x and O_3. It should also be noted that there is no general agreement among investigators concerning these health-related criteria (15).**

[Text continues on p. 42]

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*In Table 13 and throughout this report, hydrocarbons are referred to as HC; carbon monoxide as CO; oxides of nitrogen as NO_x, expressed as NO_2; and oxides of sulfur as SO_x, expressed as SO_2.

**A National Academy of Sciences' report released in September 1974 may have resolved this issue, since it concluded that EPA standards are not only scientifically sound but in some cases represented limited safety standards (Associated Press, "Air Pollution Rules Backed by Scientists," Los Angeles Times, 5 September 1974).

Table 13. Milestones in U.S. air pollution legislation and regulations.

Time	Event	Result
1959	California initiates motor vehicle emission controls.	Adoption of California standards to control exhaust HC and CO.
1960	Supplemental California motor vehicle emission control legislation.	Adoption of California standards to control emissions from crankcase blowby.
1963	Passage of the federal Clean Air Act.	Authorized grants to state and local agencies to assist with their air pollution control problems. Also gave limited authority to the federal government in interstate pollution problems.
1963	Supplemental California motor vehicle emission control legislation.	Adoption of California diesel smoke standards.
1963	California initiates control of crankcase emissions.	Crankcase emission control required on 1963 models in California. Improved crankcase emission control on 1964 models.
1965	Amendments to federal Clean Air Act.	Authorized the Secretary of the Department of Health, Education, and Welfare to control emissions from motor vehicles.
1966	Federal Motor Vehicle Emission Standards adopted.	Applicable to 1968 model vehicles; see below, 1968.
1966	California initiates control of exhaust hydrocarbons and carbon monoxide.	Hydrocarbon and carbon monoxide exhaust emission controls required on 1966 California vehicles.
1967	Passage of Air Quality Act.	Provided for public hearings on air pollution control.
1968	Implementation of 1966 federal Motor Vehicle Standards.	Required some control of exhaust HC (8.2 g/mi) and CO (22 g/mi) from light-duty vehicles* and 100% control of crankcase emissions (HC) from gasoline-fueled cars, buses and trucks.

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*Until 1973 refers to self-propelled vehicles designed for street or highway use weighing less than 6000 pounds and carrying no more than 12 passengers. After 1973, separate standards are established for light-duty (less than 4000 pounds) trucks.

Table 13 (continued)

Time	Event	Result
1968	Revised federal motor vehicle emission standards published.	Applicable to 1970 and 1971 model years; see below, 1970 and 1971.
1970	Implementation of 1968 revised federal motor vehicle emission standards for hydrocarbons and carbon monoxide.	More stringent control of HC (4.6 g/mi) and CO (47 g/mi) from light-duty vehicles, of exhaust HC and CO emissions from gasoline fueled heavy-duty vehicles, and of smoke emissions from diesel engines for heavy-duty vehicles. (These controls represented a reduction in HC emissions of about 70% and in CO emissions of about 60%.)
1970	Clean Air Act amended.	Creation of EPA to carry out provisions of the Act including promulgation of air quality standards and specific mobile and stationary emission standards. States are required to prepare specific implementation plans on how they propose to attain air quality standards. Calls for at least 90% reduction by 1975 of the CO and HC motor vehicle emissions from their 1970 model year values and a reduction of at least 90% by 1976 in NO_x emissions from measured values in 1971 model cars. (Due to prior 1968 reductions, effectively calls for about a 98% clean-up in emissions from pre-control vehicles.)
1970	Standards published modifying methods of evaluating emissions.	Applicable to 1972 models; see below, 1972.
1971	Implementation of 1968 federal motor vehicle emission standards for fuel evaporative emissions.	Fuel evaporative emission controls effective with 1971 model year (6 g/test).
1971	EPA publishes advanced notice of its intention to control or prohibit fuel additives.	Proposed rule-making concerning the addition of alkyl lead to gasoline fuels for motor vehicles at earliest possible date.

Table 13 (continued)

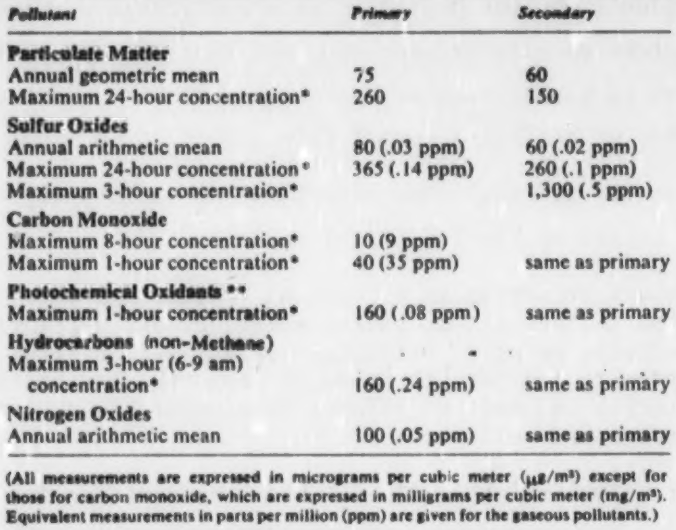
Time	Event	Result
1971	EPA publishes notice of proposed rule-making concerning the requirement for the preparation of state implementation plans necessary to achieve national ambient air quality standards.	Attention was called to the potential need to develop aftermarket strategies to control motor vehicle emissions, which might include vehicle inspection programs, mandatory maintenance, and/or retrofit control systems for the existing auto population.
1971	National primary and secondary ambient air quality standards published.	Standards included hydrocarbons, carbon monoxide and oxides of nitrogen, most closely associated with motor vehicle emissions, and photochemical oxidants, particulate matter and sulfur dioxide.
1971	First federal standards issued requiring control of oxides of nitrogen emissions and prescribing measurement techniques.	These controls for oxides of nitrogen were applicable to 1973 model light-duty motor vehicles; see below, 1973.
1971	Standards promulgated to prescribe future control of motor vehicle emissions in 1975 and 1976 model vehicles.	Imposes 1975 exhaust HC and CO emission requirements and 1976 NO_x emission requirements applicable to light-duty vehicles; see below, 1975 and 1976.
1972	Implementation of modified methods for evaluating emissions.	Modified method (Constant Volume Standard) of evaluating exhaust HC and CO emissions from light-duty vehicles. Improved method of test operations, exhaust sampling and gas analysis to make emission measurements more representative of actual discharges from in-use vehicles. Includes both a cold start (after 12-hour storage) and hot start (after 10-minute wait) and the computation of a weighed average as a basis for 1975 and 1976 numerical standards, see below.
1973	EPA postpones NO_x standards imposed in 1971 and scheduled for 1976 model light-duty vehicles to 1977.	Interim standards set for NO_x emissions from 1976 light-duty vehicles; see below, 1976.
1973	EPA announces separate CO and HC standards for 1975 model light-duty trucks as required by federal court ruling.	More lenient 1975 CO and HC standards set for light-duty trucks weighing less than 6000 pounds, see below, 1975.

Table 13 (continued)

Time	Event	Result
1973	Implementation of 1971 NO_x standards.	Maximum emission ceiling of 3.0 g/mi for NO_x.
1973	EPA revises standards imposed in 1971 and scheduled for 1975-76 model vehicles; imposes interim standards.	Emission controls on HC and CO in 1975 models delayed to 1976. Interim national standards imposed and more stringent interim California standards announced; see below, 1976.
1975	Scheduled implementation of separate standards for CO and HC imposed in 1973 on 1975 model light-duty trucks.	Schedule standards for 1975 model light-duty trucks are 2 gram/mi for HC, 20 gram/mi for CO.
1975	Scheduled implementation of 1971 standards for further control of motor vehicle emissions.	Scheduled reductions of 97, 96 and 93 percent in HC, CO and NO_x , respectively from uncontrolled levels. Imposes maximum emission ceilings of 0.41 grams/mi for HC; 3.4 gram/mi for CO. (Delayed until 1976, see below.)
1975	Scheduled implementation of interim standards imposed in 1973 on 1975 model vehicles.	Scheduled maximum interim emission ceilings of 1.5 g/mi for HC; 15 g/mi for CO, and 3.1 g/mi for NO_x. California ceilings are 0.9 g/mi for HC; 9 g/mi for CO; and 2.0 g/mi for NO_x.
1976	Scheduled implementation of 1971 NO_x emission standards for light-duty vehicles.	Scheduled maximum emission ceiling of 0.41 g/mi for NO_x emission from light-duty vehicles. (Postponed to 1977, see below.)
1976	Scheduled implementation of interim standards imposed in 1973 for NO_x emissions.	Scheduled implementation of interim standards of 2 g/mi for NO_x emissions from light-duty vehicles.
1976	Rescheduled implementation of 1971 standards for further control of motor vehicle emissions.	Imposes maximum emission ceilings of 0.41 g/mi for HC; 3.4 g/mi for CO on light-duty vehicles.
1977	Rescheduled implementation of 1971 standards on NO_x emissions.	Imposes a maximum emission ceiling of 0.4 g/mi for NO_x emissions from light-duty vehicles.

Sources: References 12, 13, 14 and 15.

Table 14. National ambient air quality standards.



Pollutant	*Primary*	*Secondary*
Particulate Matter		
Annual geometric mean	75	60
Maximum 24-hour concentration*	260	150
Sulfur Oxides		
Annual arithmetic mean	80 (.03 ppm)	60 (.02 ppm)
Maximum 24-hour concentration*	365 (.14 ppm)	260 (.1 ppm)
Maximum 3-hour concentration*		1,300 (.5 ppm)
Carbon Monoxide		
Maximum 8-hour concentration*	10 (9 ppm)	
Maximum 1-hour concentration*	40 (35 ppm)	same as primary
Photochemical Oxidants **		
Maximum 1-hour concentration*	160 (.08 ppm)	same as primary
Hydrocarbons (non-Methane)		
Maximum 3-hour (6-9 am) concentration*	160 (.24 ppm)	same as primary
Nitrogen Oxides		
Annual arithmetic mean	100 (.05 ppm)	same as primary

(All measurements are expressed in micrograms per cubic meter ($\mu g/m^3$) except for those for carbon monoxide, which are expressed in milligrams per cubic meter (mg/m^3). Equivalent measurements in parts per million (ppm) are given for the gaseous pollutants.)

*Not to be exceeded more than once a year.
**Expressed in ozone equivalents.

Source: Reference 16.

Table 15. Summary of Federal Motor Vehicle Emission Standards — Light Duty Vehicles

Type of Emission	Typical Uncontrolled Levels	Controlled Emission Levels (g/mi)							
		1968	1970	1971	1972	1973	1975[1]	1976	1977
HC	16.3	8.2	4.6	4.6	3.4	3.4	1.5	0.41	0.41
CO	124	72	47	47	39	39	15	3.4	3.4
NO_x	7.1	N/R[2]	N/R	N/R	N/R	3.0	3.1	2.0	0.41
Fuel Evaporatives (g/test)	30	N/R	N/R	6.0	2.0	2.0	2.0	2.0	2.0

[1] California standards are (g/mi): 0.9 for HC, 9 for CO, and 2.0 for NO_x.
[2] Not required.
Note: Values up to 1975 expressed in terms of 1972 Federal Test Procedures. Values after 1975 are based on a modified computation procedure.

Source: References 12, 13, 14 and 15.

While the legislation does not define the term "public health", the Senate report on the Act indicates that the standards would not have to protect individuals who are dependent on a controlled environment such as patients in intensive care or newborns, but must protect particularly sensitive citizens such as bronchial asthmatics and emphysematics who otherwise are capable of leading a normal life (15).

The Act itself provides some guidelines on the meaning of "public welfare". It states in Section 302(h) that:

> "All language referring to effects on welfare includes, but is not limited to, effects on soils, water, crops, vegetation, manmade materials, animals, wildlife, weather, visibility, and climate, damage to and deterioration of property, and hazards to transportation, as well as effects on economic values and on personal comfort and well-being."

The information in Tables 13 - 15 has been verified for accuracy as of this writing (12/74). However, in view of current controversies (e.g., the necessity for imposing as stringent controls for NO_x as now are scheduled), it appears likely that further changes may be made in the level of emission controls shown in Table 15. Likewise, due to the fuel penalties associated with present and future emission control devices and the current petroleum shortage, it is also quite possible that postponements may occur in future scheduled implementation dates. A reassessment of the Ambient Air Quality Standards is also being called for, especially with respect to their inclusion of dual standards, their exclusion of regional standards, and their disregard of state standards. In fact, the entire Clean Air Amendments of 1970 have been attacked on the above issues as well as on the following ones (23):

- Dubious basis for the requirements of the Act for 90 percent reduction in automotive exhaust emissions.
- Ambiguity of the language describing the purpose of the Act which has led to court actions regarding degradation of the air.
- Ambiguous definitions of national air quality standards in terms of "attainment and maintenance of public health."
- Mandated time schedules which are claimed to prevent both the administrator and the states from doing as thorough a job of developing criteria, standards, regulations, test methods, plans and programs as they could have done, had there been more flexible time schedules.

- Mandated time sequences which further impede making reasonable revisions in air quality criteria documents.
- Lack of a straightforward mechanism for revising air quality boundaries set in 1970.

Regardless of the numerous probable defects in the legislation, discussed briefly above, its several effects on energy production and consumption, and the costs incurred and to be incurred, there is no doubt that urban air pollution will be reduced over the next decade if the regulations imposed are adhered to. These positive expectations are examined below through a comparison of the status of urban air quality prior to controls and its predicted future status under the existing regulations.

Pre-Control and Expected Future Status of Urban Air Quality

AMBIENT AIR QUALITY LEVELS. Although the goals for ambient air quality are expressed on a nationwide basis, the only meaningful assessment of the existing quality of urban air and its expected future status must be made on the basis of observations on individual urban areas. Table 16, therefore, presents air quality data on six urban regions, essentially before significant regulatory effects were experienced. Almost all of the

Table 16. Air quality data for six major urban regions prior to significant air quality regulations compared to the National Ambient Air Quality Standards.

Region	Carbon Monoxide (AAQS* = 10 mg/m^3)	Oxides of Nitrogen (AAQS = 100 μg/m^3)	Photochemical Oxidants (AAQS = 160 μg/m^3
	Ambient Air Quality (1967)	Ambient Air Quality (1969)	Ambient Air Quality (1967)
Chicago	36.8 mg/m^3	301 μg/m^3	314 μg/m^3
Denver	34.5 mg/m^3	59 μg/m^3	411 μg/m^3
Los Angeles	43.7 mg/m^3	292 μg/m^3	1274 μg/m^3
New York	24.5 mg/m^3	187 μg/m^3	359 μg/m^3
Philadelphia	26.5 mg/m^3	241 μg/m^3	333 μg/m^3
Washington	26.5 mg/m^3	129 μg/m^3	509 μg/m^3

*Ambient Air Quality Standard

Source: Reference 15.

regions shown in Table 16 exceed each of the air quality standards by at least a factor of about 3. Naturally, however, the degree of control which needs to be exercised in each region is not directly related to the extent to which the air quality standards are exceeded, but rather depends on a number of other factors, including the prevailing meteorological conditions, the source of pollution emissions, and the background level in the region. In an attempt to clarify these interrelationships and their bearing on transportation-related pollutant emissions, first one basic relationship between the air quality standards and emissions is discussed. The example chosen is considered to be particularly appropriate, because it bears directly on the relationship between NO_2 and air quality, and the emission control levels required to reduce smog to acceptable levels.

REACTIVE HYDROCARBONS, NITROGEN DIOXIDE, AND SMOG. In this regard it is noted that in Table 16, photochemical oxidants, the principal chemical species responsible for smog conditions*, are one of the three basic measurements selected to portray urban air quality. Since the relationship between photochemical oxidants and the reactive hydrocarbons and oxides of nitrogen emitted by gasoline-fueled vehicles is primarily responsible for the existing controls on these emissions, a brief description of the current understanding of this relationship is given below. The information upon which this description is based was drawn, for the most part, from Reference 19.

The oxidant found in the largest quantity in polluted atmospheres is ozone (O_3). In order to photochemically generate the observed O_3 concentrations, however, a process other than direct light absorption of oxygen (O_2) must be involved. A comparison of the absorption characteristics of the major atmospheric pollutants indicates that nitrogen dioxide is the most efficient absorber of that portion of the sun's ultraviolet light which reaches the earth's surface, and further, that this absorption of ultraviolet light leads to a complex series of reactions represented by the following three equations:

---

*Expressed in terms of ozone (O_3) equivalents.

$$NO_2 \xrightarrow[\text{light}]{\text{U.V.}} NO + O \qquad (1)$$

$$O + O_2 + M \longrightarrow O_3 + M\text{, where } M = \text{a collision molecule} \qquad (2)$$

$$O_3 + NO \longrightarrow NO_2 + O_2 \qquad (3)$$

These reactions are shown schematically in Figure 7.

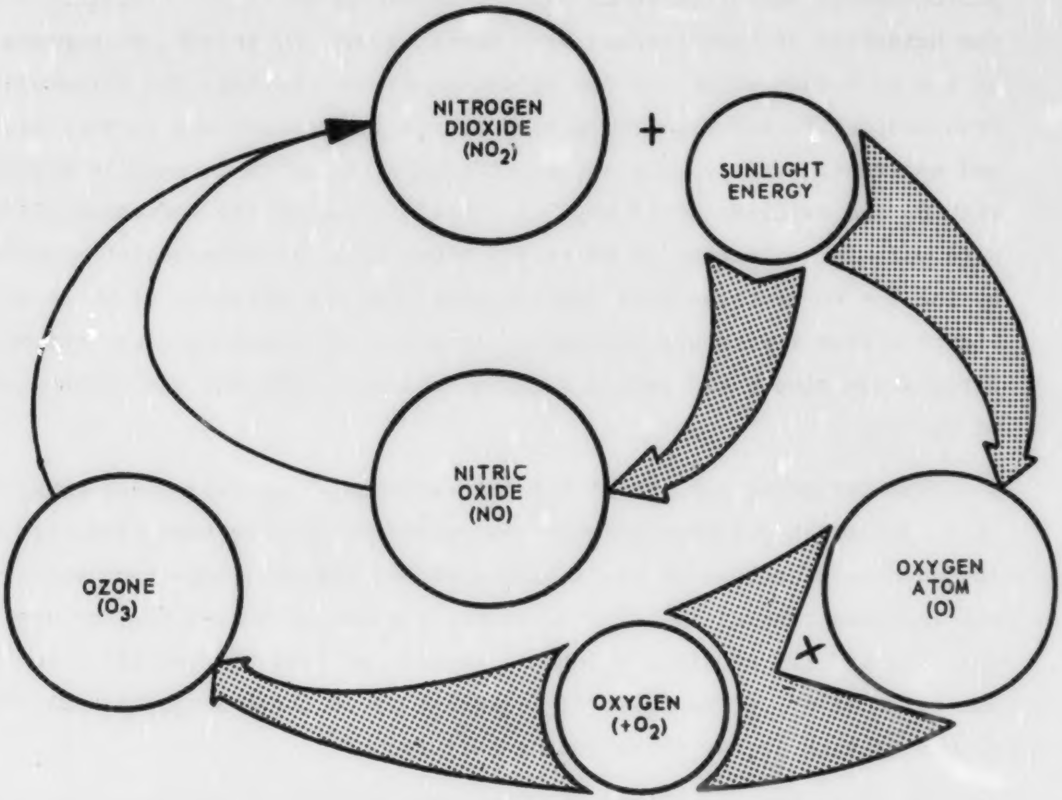


Figure 7. Atmospheric nitrogen dioxide photolytic cycle.

Source: Reference 19.

Because of known steady-state relationships between these chemical species and the observed changes which do occur in the atmosphere, it is also known that reactions other than Equations 1 to 3 must also be occurring which result in the presence of higher concentrations of ozone than would occur solely on the basis of the interactions shown in Figure 7. That is, the NO_2 photolytic cycle of Figure 7 explains the initial formation of ozone in polluted atmospheres, but it does not explain how concentrations can develop as large as those which have been measured.

Laboratory experimentation and atmospheric measurements indicate that certain reactive hydrocarbons provide the necessary added reactants. Figure 8 shows schematically how hydrocarbons are thought to be involved in photochemical oxidation reactions. Examination of Figure 8 indicates that the oxidation of hydrocarbons by O atoms is not, by itself, an explanation of the O_3 accumulation nor the oxidation of NO. Rather, the intermediate free radical formed from the O atom attack on hydrocarbons is very reactive and apparently undergoes a series of changes in which it readily reacts with O_2 and oxidizes NO to NO_2. A consideration of the indicated alternate path for oxidation of NO to NO_2 shows that the intermediates produced by the O + RH reaction must oxidize more than one molecule of NO to NO_2. Figure 8 thus represents the manner in which hydrocarbons enter the NO_2 circulation scheme and permit a rapid buildup of NO_2 and the accumulation of O_3.

The foregoing outline of the interactions which take place among chemical species in polluted atmospheres resulting in smog conditions has been included here because it (1) illustrates one specific impact of motor vehicle emission control legislation (i.e., control of HC and NO_x) on urban air quality, and (2) provides a logical transition from the consideration of urban air quality to the following examination of the contribution of the transportation sector to polluting emissions.

VEHICLE EMISSION CONTROL LEVELS. The amounts of air pollutant emitted by various sources and the relative contribution of each source to total emissions is shown in Table 17 on a nationwide basis. As is well documented in numerous other references, motor vehicles prior to control of their emissions contributed an estimated 44 percent of the major air pollutants emitted in the nation (and 58 percent of all CO, HC, and NO_x emissions).

To illustrate the impact on urban air quality of achieving the Clean Air Act's objective of reducing CO, HC and NO_x emissions from mobile sources by some 90 percent over their 1970-71 levels, emission projections are shown for mobile and stationary sources in Tables 18-23 for the six regions for which air quality data is presented in Table 16. It is noted that the pro-

[Text continues on p. 52]

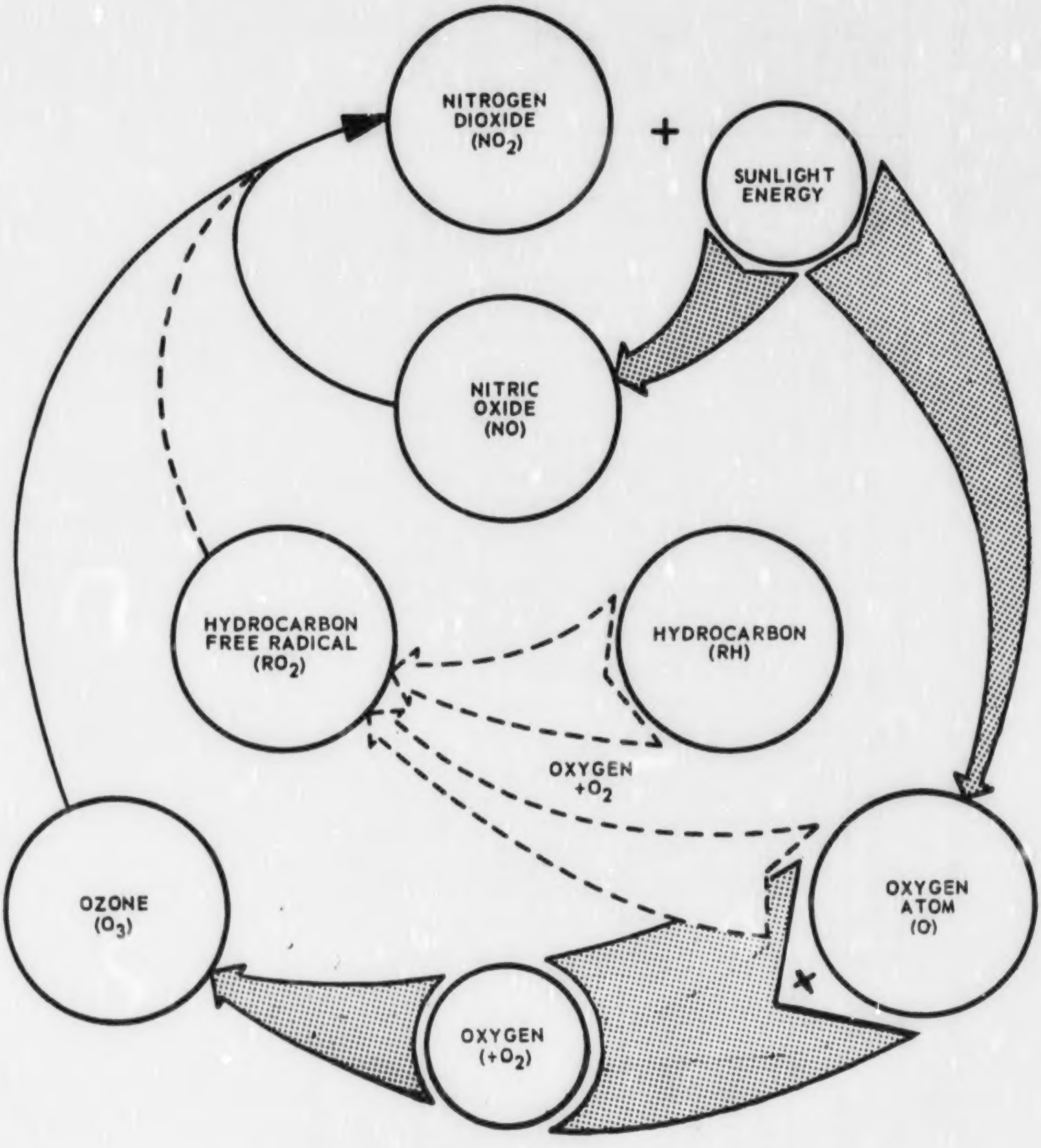


Figure 8. Interaction of hydrocarbons with atmospheric nitrogen dioxide photolytic cycle.

Source: Reference 19.

Table 17. Estimates of nationwide polluting emissions by quantity and percentage and by source, 1969.

Sources	Emissions (10^6 tons)					Emission Components (percent)					Percent of Total by Source
	CO	Part[1]	SO_x	HC	NO_x	CO	Part[1]	SO_x	HC	NO_x	
Transportation	111.5	0.8	1.1	19.8	11.2	73.7	2.3	3.3	52.9	47.1	51.4
Motor vehicles	*98.0*	*.4*	*.3*	*17.1*	*8.7*	*64.7*	*1.1*	*0.9*	*45.7*	*36.6*	*44.2*
Fuel Combustion in stationary sources	1.8	7.2	24.4	0.9	10.0	1.2	20.5	73.0	2.4	42.0	15.7
Industrial processes	12.0	14.4	7.5	5.5	0.2	7.9	40.8	22.5	14.7	0.8	14.1
Solid waste disposal	7.9	1.4	0.2	2.0	0.4	5.2	4.0	0.6	5.3	1.7	4.2
Miscellaneous	18.2	11.4	0.2	9.2	2.0	12.0	32.4	0.6	24.7	8.4	14.6
TOTAL	151.4	35.2	33.4	37.4	23.8						
Percent of Total by Component						53.8	12.5	11.9	13.3	8.5	100.0

[1] Particulates.

Source: Reference 15.

Table 18. Emission projections for Chicago Air Quality Control Region.

Emission Type	Source of Emission	Quantity of Emissions per year (10^3 tons/yr)					Emissions for AAQS to be met	Time Period Standard Attained
		1971	1975	1977	1980	1985		
Carbon Monoxide	Mobile	2462	1696	1229	719	308		
	Stationary	157	61	62	63	64		
		2619	1757	1291	782	372	573	1980-85
Hydrocarbons	Mobile	214	115	82	46	19		
	Stationary	51	17	17	17	18		
		265	132	99	63	37	135	1975
Nitrogen Dioxide	Mobile	133	140	100	71	31		
	Stationary	243	233	237	241	245		After 1985
		376	373	337	312	276	125	

Source: Reference 15

Table 19. Emission projections for Denver Air Quality Control Region.

Emission Type	Source of Emission	Quantity of Emissions per year (10^3 tons/yr)					Emissions for AAQS to be met	Time Period Standard Attained
		1971	1975	1977	1980	1985		
Carbon Monoxide	Mobile	564	430	320	194	89		
	Stationary	46	29	29	30	32		
		610	459	349	224	121	170	1980-85
Hydrocarbons	Mobile	76	60	33	19	8		
	Stationary	22	11	11	11	12		
		98	71	44	30	20	31	1980
Nitrogen Dioxide	Mobile	31	36	29	20	9		
	Stationary	33	41	44	48	59		
		64	77	73	68	68	100	Pre-control

Source: Reference 15.

Table 20. Emission projections for Los Angeles Air Quality Control Region.

Emission Type	Source of Emission	Quantity of Emissions per year (10^3 tons/yr)					Emissions for AAQS to be met	Time Period Standard Attained
		1971	1975	1977	1980	1985		
Carbon Monoxide	Mobile	4745	3415	2505	1489	656		
	Stationary	252	181	185	188	195		
		4997	3596	2690	1677	851	1086	1980-85
Hydrocarbons	Mobile	876	420	343	237	146		Unattainable under present regulations
	Stationary	365	347	354	365	365		
		1241	767	697	602	511	*	
Nitrogen Dioxide	Mobile	402	442	349	231	103		
	Stationary	146	139	142	146	146		After 1985
		548	581	491	377	249	186	

*Requires reduction of greater than 90 percent.

Source: Reference 15.

Table 21. Emission projections for New York Air Quality Control Region.

Emission Type	Source of Emission	Quantity of Emissions per year (10^3 tons/yr)					Emissions for AAQS to be met	Time Period Standard Attained
		1971	1975	1977	1980	1985		
Carbon Monoxide	Mobile	5062	3437	2484	1444	614		
	Stationary	198	98	98	98	99		
		5260	3535	2582	1542	713	2065	1977-80
Hydrocarbons	Mobile	306	163	115	64	26		
	Stationary	59	28	29	29	31		
		365	191	144	93	57	146	1977
Nitrogen Dioxide	Mobile	266	276	215	139	60		
	Stationary	436	358	376	407	467		After 1985
		702	634	591	546	527	375	

Source: Reference 15.

Table 22. Emission projections for Philadelphia Air Quality Control Region.

Emission Type	Source of Emission	Quantity of Emissions per year (10^3 tons/yr)					Emissions for AAQS to be met	Time Period Standard Attained
		1971	1975	1977	1980	1985		
Carbon Monoxide	Mobile	1846	1290	939	552	239		
	Stationary	806	556	562	570	584		
		2652	1846	1501	1122	823	824	1985
Hydrocarbons	Mobile	219	120	85	48	20		
	Stationary	243	108	109	112	115		
		402	228	194	150	185	208	1970-77
Nitrogen Dioxide	Mobile	116	124	97	64	28		
	Stationary	308	306	323	347	397		
		424	430	420	411	425	176	After 1985

Source: Reference 15.

Table 23. Emission projections for Washington Air Quality Control Region.

Emission Type	Source of Emission	Quantity of Emissions per year (10^3 tons/yr)					Emissions for AAQS to be met	Time Period Standard Attained
		1971	1975	1977	1980	1985		
Carbon Monoxide	Mobile	1233	1033	787	495	240		
	Stationary	45	20	20	21	22		
		1278	1053	807	516	262	482	1980-85
Hydrocarbons	Mobile	225	148	110	66	30		
	Stationary	37	18	18	19	20		
		262	166	128	85	50	44	After 1985
Nitrogen Dioxide	Mobile	52	67	55	38	19		
	Stationary	67	87	92	101	119		
		119	154	147	139	138	92	Pre-control

Source: Reference 15.

jections of Tables 18-23 were made in 1971, prior to the 1973 postponement of the 1975 and 1976 motor vehicle emission control standards and prior to the recent relaxation of stationary source controls due to the current energy shortage. Thus, the emission levels for 1977-1985 shown in these tables will not be attained until at least one year after the dates shown in Tables 18-23.

According to the report of the RECAT Committee (15) from which this data was excerpted*:

> "The air quality data [Table 16] was used to calculate the degree or percentage of control needed to achieve the air quality standard. This percentage reduction was applied to total emissions of the pollutant to calculate a target emission limit for the entire urban area. Control of automotive emissions was assumed to follow the national emissions standards now in effect and prescribed in the Act. Severe emission control was assumed on stationary sources based on existing and developing technology. These were:
>
> a. For CO, 50-percent control of existing stationary sources between now and 1975; 90-percent control of new sources after 1975.
>
> b. For hydrocarbons, 60-percent control of existing and 90-percent control of new.
>
> c. For NO_x, 20-percent of existing; 50-percent of new.
>
> Realistic growth rates were assumed for each situation based on data available for the metropolitan area. Land use planning and traffic control were not considered. Clearly, these are the only options remaining where source control will not produce the needed air quality in the mandatory schedule."

If the mandatory schedule for attainment of the primary air quality standards remains unchanged (i.e., 1975 extended to 1977), it is also clear that this schedule will not be met for most of the major pollutants in most of the six urban areas examined above—unless some traffic control is exercised and/or land use restrictions are imposed. However, taking a somewhat broader view, it could also be inferred from the data presented that the air pollution problems in most of these urban areas will have been materially reduced by 1977-1980 and that, in most cases, the air quality standards will have been attained by 1985.

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*It is noted that many of these values have subsequently been revised.

The degree to which the effects of the current energy shortage might offset these planned schedules for the reduction of automotive emissions, thus requiring implementation of traffic controls in order to meet the scheduled attainment of national air quality standards, is discussed in Volume 1 (Part II, Section 6) of this study. The estimated effect of exercising certain of the available options on the reduction of pollution emissions is illustrated in Figures 9-11.

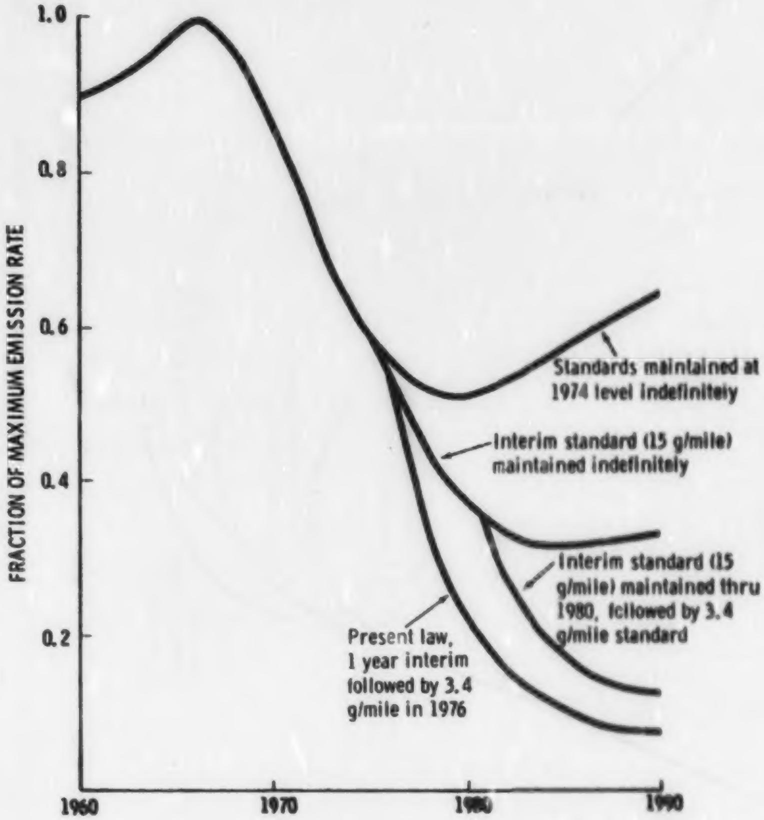

Figure 9. Projected emissions of carbon monoxide by automobiles in urban areas under various assumptions.

Source: Reference 24.

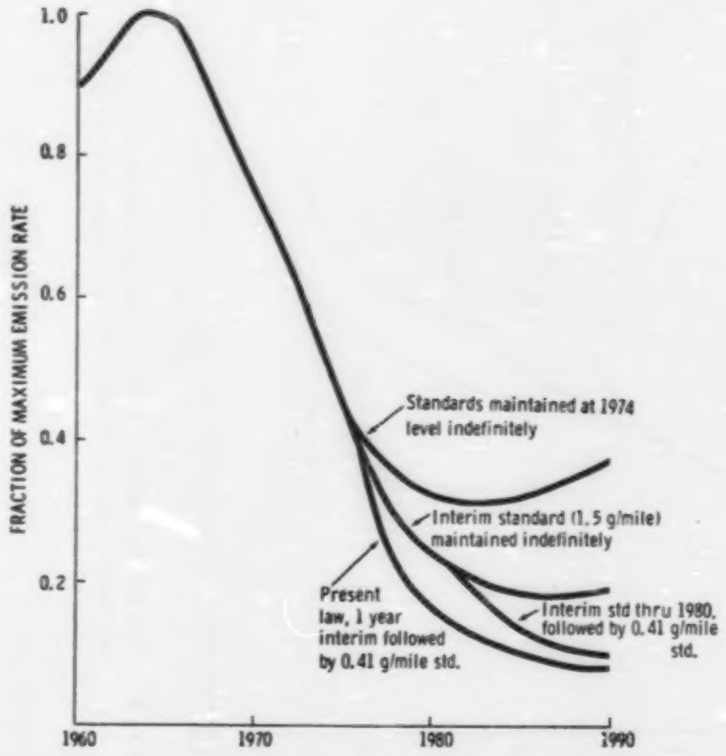

Figure 10. Projected emissions of hydrocarbons by automobiles in urban areas under various assumptions.

Source: Reference 24.

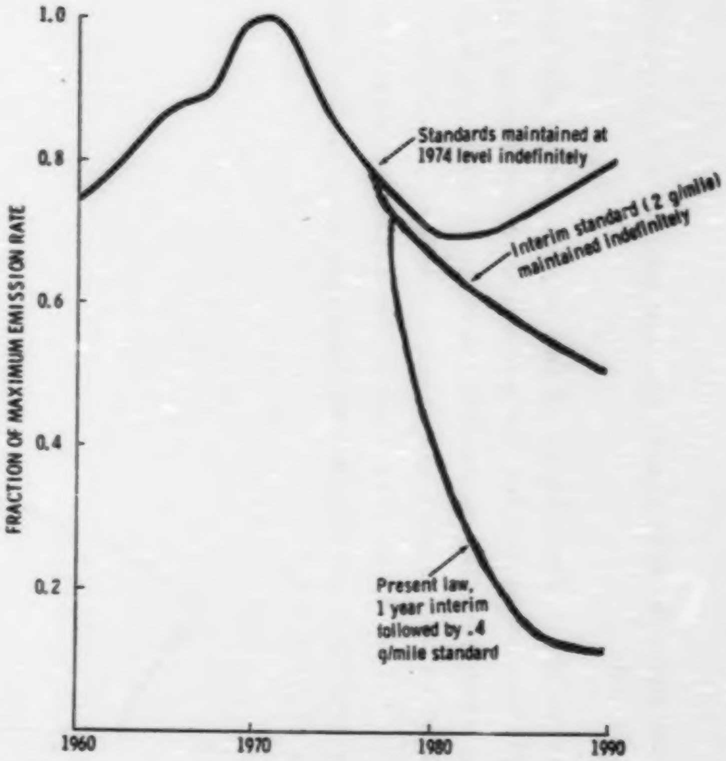

Figure 11. Projected emissions of oxides of nitrogen by automobiles in urban areas under various assumptions.

Source: Adapted from reference 24.

TRANSPORTATION-RELATED ENERGY CONSUMPTION

As with the problem of urban traffic congestion, in examining energy usage a distinction must be made between the underlying causes for, or reasons behind, the exceptionally high total energy usage of the U.S.(and the transportation sector's unusually large share of the total), and the effect of this usage on past and projected future energy consumption.

Perhaps the most visible cause for continually increasing U.S. energy consumption—in all sectors—has been the national "cheap fuel" policy vigorously pursued since at least the early 1930s. The availability of gasoline, for instance, to the transportation sector at a fraction of the price charged elsewhere in the world unquestionably encouraged the increasing dependence of the U.S. public on the private automobile for travel. Concomitantly, however, the convenience and adaptability of the private automobile to satisfying personal travel needs, as well as apparently satisfying certain other social and psychological needs, also stimulated the demand for gasoline and spurred the oil industry to (1) continually increase productive capacity from domestic and international resources, and (2) produce innovative processes permitting greater proportions of gasoline to be extracted per barrel of crude oil (i.e., thermal and catalytic cracking).

Current issues such as the impact of motor vehicle emission controls on automotive fuel efficiency and the potential impact on energy consumption of actions which could be supported by UMTA and EPA are examined in Volume 1 (Part II, Sections 5 and 6) of this study. Volume 2 presents a method for estimating the degree to which legislative and policy changes, such as a national policy to induce increased transit patronage, will affect future transportation-related energy demand. The purpose of the following text, however, is to present information on the current status and past and future trends in U.S. energy consumption, with special emphasis on petroleum consumption by the transportation sector. This information comprises the database for the analysis presented in Volumes 1 and 2.

Past Trends and Current Status

As shown in Table 24, in the period from 1947 to 1970, gross energy* consumption increased each year over the previous year in all but three years, increasing from 33.0 quadrillion Btu in 1947 to 67.4 quadrillion Btu in 1970. This represents a 3.1 percent annual rate of growth of energy demand. During the same period, net energy inputs increased from 19.2 quadrillion Btu to 56.0 quadrillion Btu for an average annual rate of growth of 2.8 percent. Shown also in Table 24 is the gradual decline in the ratio of energy inputs to GNP; the increase in gross and net energy per capita; and the decline in overall conversion efficiency from close to 90 percent in 1947 to 83 percent in 1970.

Table 24. Selected United States economic and energy indicators, 1947-1970.

Year	Gross energy input (Quadrillion Btu)	Net energy input (Quadrillion Btu)	Population (Millions)	Gross National Product (Billion of $ 1958)	Energy/GNP (1000's of Btu)	Gross energy/capita (Millions of Btu)	Net energy/capita (Millions of Btu)	Conversion Efficiency (Percent)
1947	33.0	29.2	144.1	309.9	106.4	229.0	202.8	88.5
1948	33.9	29.1	146.6	323.7	104.7	231.2	198.6	85.8
1949	31.5	27.3	149.2	324.1	97.2	211.1	182.7	86.5
1950	34.0	29.7	152.3	355.3	95.7	223.2	194.8	87.3
1951	36.8	32.1	154.9	383.4	96.0	237.6	206.9	87.1
1952	36.5	31.6	157.6	395.1	92.4	231.7	200.6	86.6
1953	37.6	32.6	160.2	412.8	91.1	234.7	201.1	85.7
1954	36.3	31.2	163.0	407.0	89.2	222.7	191.5	86.0
1955	39.7	34.3	165.9	438.0	90.6	239.3	206.7	86.4
1956	41.7	35.8	168.9	446.1	93.5	246.9	211.7	85.7
1957	41.7	35.6	172.0	452.5	92.2	242.4	206.9	85.4
1958	41.7	35.5	174.9	447.3	93.2	238.4	202.8	85.1
1959	43.1	36.4	177.8	475.9	90.6	242.4	205.0	84.6
1960	44.6	38.2	180.7	487.7	91.4	246.8	211.5	85.7
1961	45.3	38.7	183.8	497.2	91.1	246.5	210.6	85.8
1962	47.4	40.5	186.5	529.8	89.5	254.1	217.2	86.5
1963	49.3	42.0	189.2	551.0	89.5	260.5	222.0	85.2
1964	51.2	43.6	191.8	581.1	88.1	266.9	227.3	85.5
1965	53.3	45.3	194.2	617.8	86.3	274.4	232.1	85.0
1966	56.4	47.6	196.5	658.1	85.7	287.0	242.2	83.8
1967	58.3	50.4	198.6	675.2	86.3	293.5	253.8	86.4
1968	61.7	51.7	200.6	706.6	87.3	307.5	257.7	83.7
1969	65.0	54.4	202.6	724.7	89.7	320.8	268.5	83.7
1970	67.4	56.0	204.8	720.0	93.6	329.1	273.6	83.1

Source: Reference 25, p. 11.

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*Gross energy inputs refer to the total inputs to the electrical, industrial, household and commercial, and transportation sectors and include both fuel and non-fuel uses of energy sources. Net energy inputs refer to the inputs to the final consuming sectors: industrial, transportation, and household and commercial. The conversion efficiency factor is the percent of total gross energy going into the sectors.

It is noted that the growth rates over the entire period documented in Table 24 are not truly representative of the growth rates experienced in the recent past, as can be seen in the following tabulation (25):

Year	Gross energy inputs (Quadrillion Btu)	Average annual growth rate (Percent)	Net energy inputs (Quadrillion Btu)	Average annual growth rate (Percent)
1950	34.0		29.7	
1955	39.7	3.1	34.3	2.9
1960	44.6	2.3	38.2	2.2
1965	53.3	3.6	46.3	3.5
1970	67.4	4.8	56.0	4.3

From 1965 on, there appears to have been an acceleration in the rate of growth in total energy consumption, which, as was noted earlier in this section, has also occurred in the transportation sector.

The percentage sectoral consumption of gross energy inputs is shown in Table 25 for selected years.

Table 25. Energy consumption by sector, selected years, 1947-1970.

Sector	Percent of Total Gross Energy Inputs			
	1947[1]	1955[1]	1965[1]	1970[2]
Household and Commercial	26.4	29.1	33.1	34.3
Industrial	45.1	43.7	42.0	40.3
Transportation	26.9	24.8	23.8	25.2
Miscellaneous	1.6	2.4	1.2	0.2
Total	100.0	100.0	100.0	100.0
Total gross energy input (Btu × 10^{15})	33.2	40.0	53.8	67.4

[1] Source: Reference 7, p. 255.
[2] Source: Reference 26.

Notes: A. As the classifications suffer from several defects, breakdowns should be viewed as broad approximations, e.g., commercial use includes an unknown amount of consumption by small industrial users of gas and electricity, though presumably not of coal and oil; transportation is deficient in coverage of some water-borne traffic.

B. The primary energy inputs (including theoretical primary equivalents of hydro- and nuclear power) of electric utilities have been allocated according to shares of sectors of utility electricity sales.

According to the data of Table 25 then, transportation's share of gross energy inputs has been about 25 percent of the total over the period examined. Over this same period, there has been a marked increase in the share of total energy inputs by the household and commercial sector, and an inversely proportionate decrease in the industrial sector's share. These changes can be at least partially explained by the increase in the use of electrical home appliances over this period and the shift toward a predominantly service-oriented economy.

Although the current consumption of total energy by the transportation sector is only 25 percent, it is, of course, the percentage consumption of scarce petroleum resources which is of primary concern here. Table 26 documents the percentage consumption of energy resources in 1970-1971 by source and consuming sector. According to Table 26, the transportation sector consumed 23.5 percent of total U.S. energy inputs as petroleum which, in turn, represents 43.8 percent of the total U.S. energy supply, the transportation sector's consumption of petroleum being 54 percent of the total U.S. petroleum input (23.5 ÷ 43.8). This information is illustrated schematically in Figure 12.

Table 26. Percentage consumption of gross energy inputs (Btu basis) by major resource and consuming sector, 1970-1971.

Consuming Sector	Resource					
	Coal	Natural gas, dry	Petroleum	Hydropower	Nuclear	Total
Household and Commercial	6.8	13.8	11.3	2.2	0.2	34.3
Industrial	12.0	17.6	8.9	1.7	0.1	40.3
Transportation	0.3	1.3	23.5	0.1	Neg.	25.2
Miscellaneous	0.1	Neg.	0.1	Neg.	Neg.	0.2
Total	19.2	32.7	43.8	4.0	0.3	100.0

Source: Adapted from Reference 26.

Implicit in the data shown in Figure 12 is the fact that the transportation sector's overall energy conversion efficiency is only about 25 percent

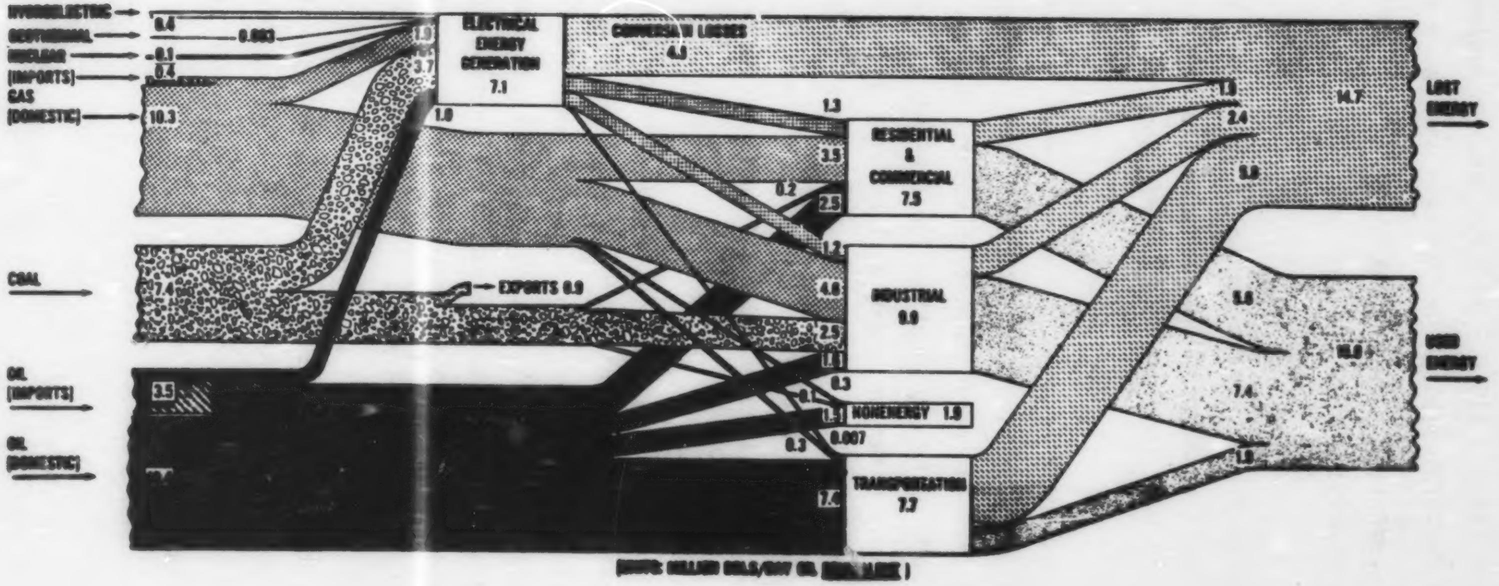


Figure 12. United States energy flow pattern, 1970.

Source: Reference 27, p. 42

$[1.9 \div (1.9 + 5.8)]$ compared to an overall conversion efficiency of about 50 percent over all sectors $[15.0 \div (15.0 + 14.7)]$. Energy conversion efficiencies of the other sectors, implied by the data in Figure 12, are:

- Electrical energy conversion - 35 percent
- Residential and commercial - 75 percent
- Industrial - 75 percent.

Two salient facts emerge from the examination of these past trends in the transportation sector's consumption of energy: transportation consumes over 50 percent of all U.S. petroleum supply and converts only 25 percent of it to useful work.

The distribution of passenger transport energy by mode from 1955-1971 is shown in Figure 13; a similar distribution of freight transport energy is shown in Figure 14. The predominance of motor vehicles as the primary energy-utilizing mode of transportation for freight and especially passenger transport is clearly shown in Figures 13 and 14, as is the still small, but most rapidly increasing utilization of transportation energy by air modes. These relationships, as they existed in 1971, are illustrated schematically in Figure 15. Actual consumption of fuels by these modes from 1960-1970 is given in Table 27.

According to Reference 29, p. 67, some 85,600 million gallons of gasoline and 6,730 million gallons of diesel fuel were consumed by highway users in 1970: automobiles, motorcycles, buses and trucks. From Figure 12, this amount was equivalent to some 7.7 million barrels of crude oil per day. Assuming that urban motor vehicle consumption represented about half of that sum, the yield from about 3.8 million barrels of crude oil per day was consumed to satisfy urban travel needs. This observation should not be taken to imply that this quantity of crude oil is refined solely to satisfy highway needs; the recent shortage of home heating fuels (representing the yield from about 2.5 million barrels per day) was at least partially compensated for by a higher production of "middle barrel" products at the expense of lighter gasoline fractions.

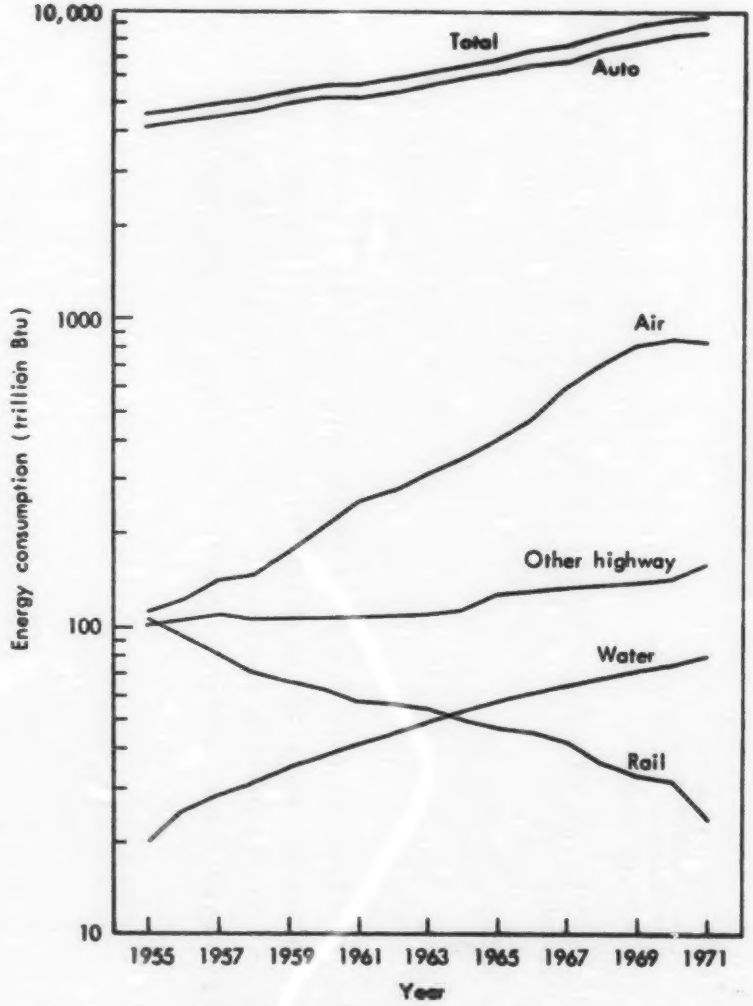


Figure 13. Domestic passenger transport energy consumption by mode, 1955-1971.

Source: Reference 28, page 13.

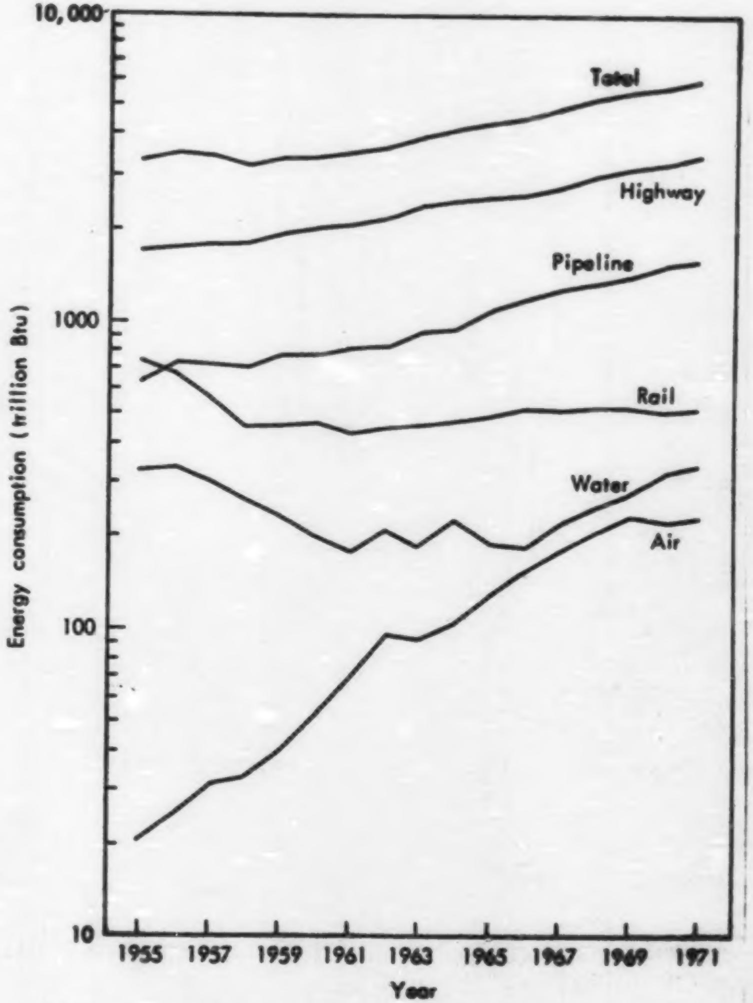
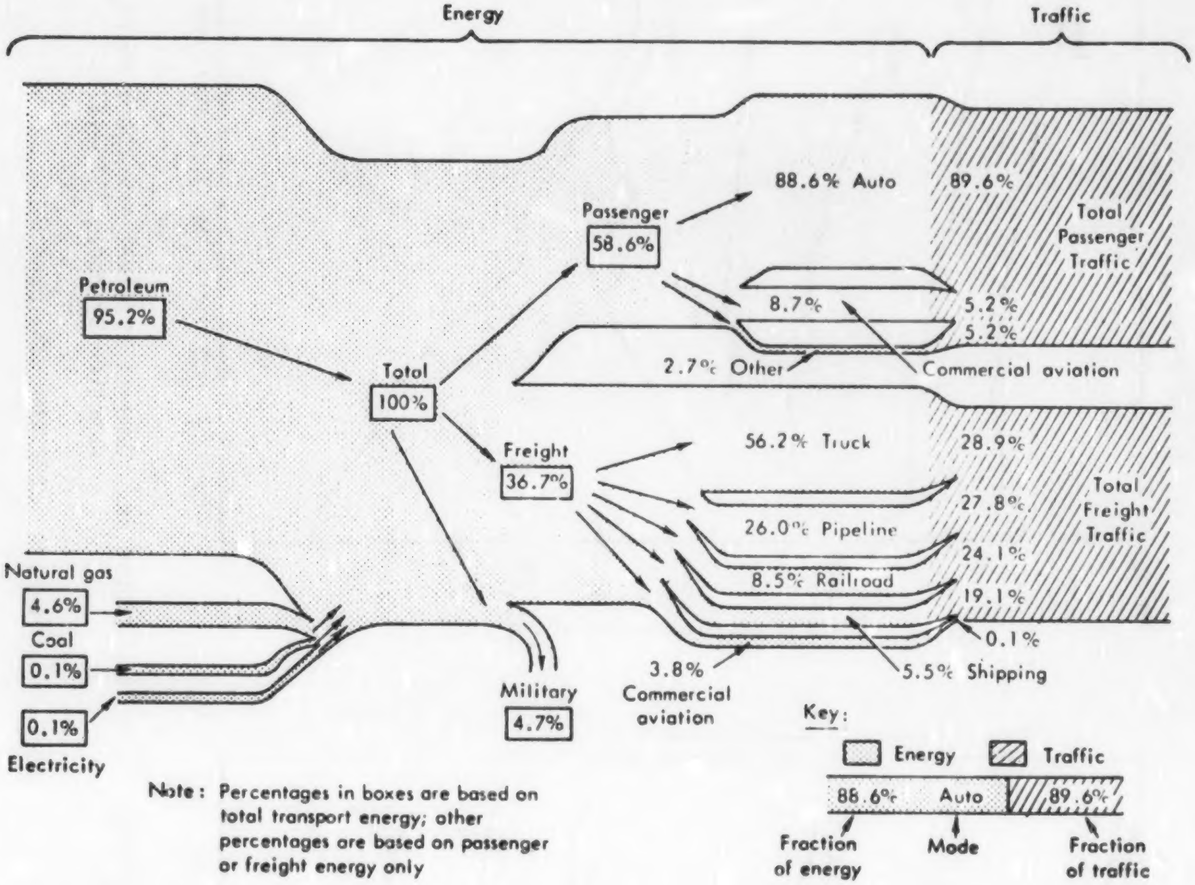


Figure 14. Domestic freight transport energy consumption by mode, 1955-1971.

Source: Reference 28, page 9.



Note: Percentages in boxes are based on total transport energy; other percentages are based on passenger or freight energy only

Figure 15. Distribution of transportation energy sources in 1971, by modal use and modal traffic.

Source: Reference 28, page 6.

The impact of the past trends in transportation-related petroleum consumption in conjunction with the predicted increases in travel documented in earlier portions of this section is discussed below as it may be expected to influence future energy consumption patterns, if left unchecked.

Table 27. Transportation fuel consumption by mode, 1960-1970.

	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970
Class I Railroads											
Locomotives											
Diesel Oil, gals × 10^6	3,464	3,375	3,456	3,537	3,624	3,736	3,920	3,883	3,917	3,919	3,804
Fuel Oil, gals × 10^6	89	94	101	90	85	77	65	47	42	33	–
Electricity, KWH × 10^6	1,050	1,037	1,094	1,018	931	933	922	832	750	610	578
Coal, tons	39,307	9,394	8,256	7,332	6,831	3,695	3,235	2,310	1,669	1,137	1,238
Motor Cars											
Diesel Oil, gals × 10^6	8	7	7	7	7	6	6	6	5	5	8
Electricity, KWH × 10^6	591	589	592	591	583	576	576	580	567	538	763
Gasoline, gals	16,112	10,497	7,033	7,591	4,585	–	–	–	–	–	–
Air											
Certificated Carriers											
Aviation Gasoline, gals × 10^6	1,189	951	738	651	589	519	398	268	128	33	15
Jet Fuel, gals × 10^6	1,331	2,073	2,808	3,291	3,830	4,650	5,670	7,523	8,891	10,113	10,085
General Aviation											
Aviation Gasoline, gals × 10^6	n/a	n/a	241	250	262	292	375	396	495	522	n/a
Jet Fuel, gals × 10^6	n/a	n/a	20	32	41	81	106	138	n/a	168	n/a
Highway											
Gasoline, gals × 10^6											
Pass. Cars + Taxis	41,169*	42,033*	43,771*	45,246*	47,567*	50,206	53,220	55,007	58,413	62,325	65,649
Motorcycles	–	–	–	–	–	69	92	103	111	123	135
Diesel + Gasoline, gals × 10^6											
Commercial Buses	618	610	610	606	622	645	637	646	655	657	644
School Buses	209	220	227	232	242	249	259	264	277	290	300
Single-unit Trucks	n/a	n/a	n/a	12,348	13,199	13,504	13,636	14,470	15,674	16,528	17,237
Combination Trucks	n/a	n/a	n/a	6,084	6,271	6,431	6,779	7,203	7,808	8,199	8,363
Water											
Vessels											
Residual Fuel Oil, gals × 10^6	3,952	3,667	3,545	3,213	3,487	3,093	3,093	3,389	3,678	3,594	3,639
Distillate Fuel Oil, gals × 10^6	787	612	665	636	672	652	699	734	766	793	840
Gasoline, gals × 10^6	n/a	n/a	n/a	n/a	n/a	n/a	485	501	533	569	598
Transit											
Electricity, KWH × 10^6											
Rapid Transit	2,098	2,108	2,115	2,125	2,171	2,185	2,075	2,194	2,250	2,291	2,261
Surface Rail	393	362	325	255	222	218	226	180	179	173	157
Trolley	417	381	346	262	204	181	166	157	157	154	143

*Includes Motorcycles.

Source: Reference 29, page 69.

Future Trends

The review of the relevant literature regarding future energy projections for the U.S. revealed that there was fairly good agreement among forecasts. For instance, Table 28 documents a comparison among estimates made in six Department of the Interior studies executed from 1968-1972. In spite of different assumptions used in these forecasts for population, economic indicators, and even conversion factors for converting units of fuel into Btu units, the resulting differences are not great, taking into account the 25-year period of some of the forecasts.

Table 28. Comparisons of energy consumption estimates from the Department of the Interior, 1968-1972 (all figures in quadrillion Btu).

	1975	1980	1985	2000
Total[1]				
U.S. Energy	80.3	96.0	118.8	191.9
Summary Review	88.8	·	133.9	191.6
TAPS Draft[2]	·	·	·	·
1970 MF&P[3]	·	·	·	202.6
U.S. Pet. 1980	·	88.1	·	·
Energy Model	76.5	88.1	·	168.6
Petroleum[1]				
U.S. Energy	35.1	42.2	50.7	71.4
Summary Review	36.1	·	47.5	66.2
TAPS Draft[2]	40.0	48.7	57.6	·
1970 MF&P[3]	·	·	·	65.3
U.S. Pet. 1980	·	38.1	·	·
Energy Model	31.9	36.0	·	57.8
Gaseous Fuels[1]				
U.S. Energy	25.2	27.7	30.4	38.5
Summary Review	28.7		38.4	50.6
TAPS Draft[2]	·	·	·	·
1970 MF&P[3]	·	·	·	46.7
U.S. Pet. 1980	·	25.6	·	·
Energy Model	22.4	25.5	·	41.7
Coal[1]				
U.S. Energy	13.8	16.1	21.6	31.4
Summary Review	16.1	·	22.3	26.7
TAPS Draft[2]	·	·	·	·
1970 MF&P[3]	·	·	·	47.0
U.S. Pet. 1980	·	·	·	·
Energy Model	17.1	[3] 17.7	·	21.6
Hydropower[1]				
U.S. Energy	3.6	4.0	4.3	5.9
Summary Review	2.8	·	3.4	6.1
TAPS Draft[2]	·	·	·	·
1970 MF&P[3]	·	·	·	6.1
U.S. Pet. 1980	·	·	·	·
Energy Model	·	3.0	·	6.1
Nuclear Power[1]				
U.S. Energy	2.6	6.7	11.7	49.2
Summary Review	4.9	·	20.8	43.5
TAPS Draft[2]	·	·	·	·
1970 MF&P[3]	·	·	·	38.1
U.S. Pet. 1980	·	·	·	·
Energy Model	·	5.7	·	43.5

NOTE: Figures for individual sources will not add to total forecast, as gaseous fuels include those synthetic fuels produced from coal and petroleum, which are also included in the respective source fuels.

[1] Full name and date of forecasts.
"United States Energy Through the Year 2000," 1972
"United States Energy—A Summary Review," 1972
"Final Environmental Impact Statement, Proposed Trans-Alaska Pipeline," 1972
"Mineral Facts and Problems, 1970" 1970 (based on 1968 data)
"United States Petroleum Through 1980," 1968
"An Energy Model for the United States" IC 8384 1968 (Based on 1966 data)

[2] TAPS Draft does not contain a forecast, per se. All recent forecasts are discussed without selection of any as a base. TAPS shown only to illustrate petroleum demand.

[3] Based on mid point of high-low forecast.

Source: Reference 25.

Figure 16 shows a similar comparison of estimates for energy consumption by the transportation sector, including the latest Department of the Interior forecast contained in Reference 25 and shown as the trend line on Figure 16. This trend is taken by INTERPLAN to represent the most likely future energy consumption pattern by the transportation sector, if no offsetting phenomena are introduced. Details of the projected trend in consumption of energy resources by major source and consuming sector in Btu units are given in Table 29. The breakdown of projected energy consumption by the transportation sector is presented in Table 30.

Table 31 presents a 1970-2000 perspective on total national energy consumption and, within this perspective, estimates of petroleum energy needs, with special reference to urban automobiles. The 1975-2000 estimates for automobile travel and urban passenger travel (Rows 5 and 6) were made by INTERPLAN by using the Department of the Interior forecasts (25) and applying to them the fractions needed for urban automobile travel as calculated by the MITRE Corporation (41). In Table 31, Rows 1 to 4 show Department of the Interior data, and Rows 5 and 6 show the results of INTERPLAN calculations.

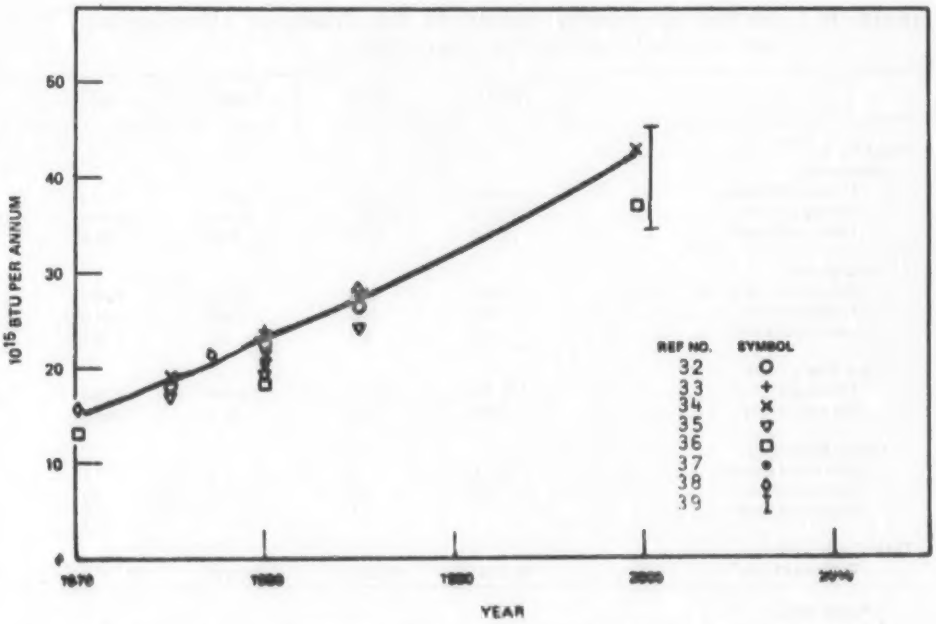


Figure 16. Transportation energy projection comparisons.

Source: Adapted from Reference 31, page 14.

Table 29. United States total gross consumption of energy resources by major sources and consuming sectors, 1971 actual, and projections to year 2000 (in trillions of Btu's).

	Coal[1]	Petroleum[2]	Natural gas	Total fossil fuels	Nuclear power	Hydro power	Total gross energy inputs	Synthetic gas distributed	Total four sector inputs	Utility elec. distributed	Total three sector inputs
1971 Household & Commercial.	390	6,545	7,346	14,281	-	-	14,281	-	14,281	3,180	17,441
Industrial	4,465	5,391	10,438	20,294	-	-	20,294	-	20,294	2,329	22,623
Transportation	7	16,139	825	16,971	-	-	16,971	-	16,971	18	16,989
Electrical Generation ...	7,698	2,417	4,125	14,240	405	2,798	17,443	-	17,443	(5,507)	-
Synthetic Gas	-	-	-	-	-	-	-	-	-	-	-
Total	12,560	30,492	22,734	65,786	405	2,798	68,989				
1975 Household & Commercial.	325	6,950	8,660	15,935	-	-	15,935	-	15,935	4,240	20,175
Industrial	4,600	6,510	11,740	22,850	-	-	22,850	-	22,850	3,010	25,860
Transportation	-	18,060	1,020	19,070	-	-	19,070	-	19,070	20	19,090
Electrical Generation ...	8,900	3,580	3,800	16,280	2,560	3,570	22,410	-	22,410	(7,270)	-
Synthetic Gas	-	-	-	-	-	-	-	-	-	-	-
Total	13,825	35,090	25,220	74,135	2,560	3,570	80,265	-	-	-	-
1980 Household & Commercial.	300	7,720	9,480	17,500	-	-	17,500	320	17,820	6,040	23,860
Industrial	4,750	7,590	12,500	24,840	-	-	24,840	380	25,220	4,170	29,390
Transportation........	-	21,440	1,400	22,840	-	-	22,840	-	22,840	30	22,870
Electrical Generation ...	10,660	5,000	3,600	19,260	6,720	3,990	29,970	-	29,970	(10,240)	-
Synthetic Gas	430	440	-	870	-	-	870	(700)	-	-	-
Total	16,140	42,190	26,980	85,310	6,720	3,990	96,020				
1985 Household & Commercial.	100	8,800	10,080	18,980	-	-	18,980	940	19,900	7,800	27,700
Industrial	5,150	9,130	13,240	27,520	-	-	27,520	1,060	28,580	6,290	34,870
Transportation........	-	25,450	1,840	27,090	-	-	27,090	-	27,090	40	27,130
Electrical Generation ...	14,220	6,650	3,450	24,320	11,750	4,320	40,390	-	40,390	(14,130)	-
Synthetic Gas	2,000	670	-	2,670	-	-	2,670	(2,000)	-	-	-
Total	21,470	50,700	28,390	100,580	11,750	4,320	116,630				
2000 Household & Commercial.	-	11,120	10,800	21,920	-	-	21,920	2,640	24,560	15,070	39,630
Industrial	6,700	14,660	17,940	39,300	-	-	39,300	2,860	42,160	15,620	57,780
Transportation........	-	40,010	2,600	42,610	-	-	42,610	-	42,610	50	42,660
Electrical Generation....	17,520	5,040	2,640	25,200	49,230	5,950	80,380	-	80,380	(30,740)	-
Synthetic Gas	7,140	550	-	7,690	-	-	7,690	(5,500)	-	-	-
Total	31,360	71,380	33,980	136,720	49,230	5,950	191,900				

[1] Includes anthracite, bituminous, and lignite.

[2] Petroleum products refined and processed from crude oil, including still gas, liquefied refinery gas, and natural gas liquids.

Source: Reference 25, page 16.

Table 30. Demand for energy inputs to the Transportation Sector, 1971, actual and projections to the year 2000.

	1971[1]	1975	1980	1985	2000
Fossil Fuels					
Petroleum					
Millions of barrels	3,004.9	3,360	3,992	4,739	7,450
Trillions of Btu	16,139	18,050	21,440	25,450	40,010
Percent of total[2]	95.0	94.6	93.8	93.8	93.8
Natural Gas					
Billions of Cubic feet...........	800	989	1,358	1,591	2,522
Trillions of Btu	825	1,020	1,400	1,640	2,600
Percent of total[2]	4.9	5.3	6.1	6.1	6.1
Total Fossil Fuels					
Trillions of Btu[3]	16,971	19,070	22,840	27,090	42,610
Percent of total[2]	99.9	99.9	99.9	99.9	99.9
Utility Electricity					
Billions of Kwhrs	5.34	6	9	11	15
Trillions of Btu	18	20	30	40	50
Percent of total[2]	.1	.1	.1	.1	.1
Total Energy Inputs					
Trillions of Btu[3]	16,989	19,090	22,870	27,130	42,660

[1] Actual data.

[2] Refers to percentage of total energy inputs to sector.

[3] Includes coal: 7 trillion Btu.

Source: Reference 25, page 27.

Table 31. Energy consumption forecast* with special reference to urban automobile transportation.

	1970	1971	1975	1980	1985	1990†	2000
1. TOTAL ENERGY							
Quadrillion (10^{15}) Btu/yr	68.8	70.0	80.3	96.0	116.6	137.8	191.9
2. ENERGY CONSUMED BY TRANSPORTATION SECTOR							
Quadrillion (10^{15}) Btu/yr	16.5	17.0	19.1	22.9	27.1	31.5	42.7
Percent of Total Energy	24.0	24.3	23.7	24.8	23.3	22.9	22.2
3. TOTAL PETROLEUM ENERGY CONSUMED							
Quadrillion (10^{15}) Btu/yr	29.6	30.5	35.1	42.2	50.7	56.9	71.4
Millions Bbl/Day	14.6	15.1	17.4	20.9	25.0	28.1	35.6
Percent of Total Energy	43.0	44.1	43.8	43.9	43.5	41.3	37.2
4. PETROLEUM ENERGY CONSUMED BY TRANSPORTATION SECTOR							
Quadrillion (10^{15}) Btu/yr	15.7	16.1	18.1	21.4	25.5	29.8	40.0
Million bbl/Day	8.0	8.2	9.3	11.0	12.9	14.7	20.5
Percent of Transportation Energy	95.5	95.0	94.6	93.8	93.8	93.8	93.8
Percent of Petroleum Consumption	53.2	54.4	53.2	52.5	51.8	52.1	57.2
5. AUTOMOBILE TRAVEL**							
Quadrillion Btu/yr			10.4	12.1	14.6	15.8	19.9
Percent of Transportation energy			54.2	52.8	53.5	50.0	46.6
Percent of Petroleum energy			29.6	28.8	28.8	27.8	27.9
Percent of Total energy			12.9	12.6	12.5	11.5	10.4
6. URBAN AUTOMOBILE TRAVEL**							
Quadrillion Btu/yr			5.7	7.1	8.5	9.5	11.8
Percent of Transportation energy			30.1	30.9	31.3	30.2	27.7
Percent of Petroleum energy			16.3	16.7	16.8	16.7	16.5
Percent of Total energy			7.1	7.4	7.3	6.8	6.2

*Department of Interior data (Reference 25). Years 1970 and 1971 are actual data (Reference 40).

†Interpolation, using 1 Bbl crude oil = 5.4×10^6 Btu.

**Derived by INTERPLAN from Reference 25 and Reference 41.

Inasmuch as the forecast for gross energy consumption and consumption by the transportation sector, shown in Tables 29-31, are used in other volumes of this study as the basic energy projection assumed to portray a continuation of past trends (if these trends are not offset by other phenomena), the assumptions upon which these projections were based are reproduced in this volume. The assumptions used in deriving the gross energy projections are given in Appendix D. The rationale underlying the transportation sector forecast is quoted below:

> "As shown, total [transportation] sector energy inputs are expected to increase from 16,989 trillion Btu in 1971 to 42,660 trillion Btu in 2000 for an average annual growth rate of 3.2 percent over the entire period.
>
> "Little significant shift in energy inputs is expected. Petroleum's share of this market will show a slight decline from 95 percent in 1971 to 93.8 percent in 2000 while natural gas will increase its share from 4.9 percent to 6.1 percent. Utility electricity is expected to retain approximately .1 percent of the market over the entire period.
>
> "The major implication of this forecast is that energy consumption in the transportation sector is expected to continue much as it has in the past. This is particularly true through 1985, for we are locked into our present systems of transportation within that time period. The long lead time required to phase in new transportation equipment precludes any radical shifts in transportation systems.
>
> "While major changes can occur after 1985 there is little evidence to indicate that the research to accomplish these major changes is being undertaken. For this time period it is necessary to consider not only the time lag associated with phasing in new equipment but also the time lag associated with the research and development of the new equipment. This does not mean that changes cannot occur. It only means that, barring a major national effort, the changes will be only evolutionary and will not have significant effects in the present century.
>
> "In preparing the forecast considerable attention was given to the problem of additional energy consumption due to environmental regulations. For automobiles little doubt exists that the regulations will reduce efficiency of utilization. Offsetting this loss of efficiency will be the movement toward a larger percent of our automobiles being in the compact category. Other factors limiting the rate of growth of energy demand in the automotive section of the sector is the growing saturation rate for

> automobiles and the declining growth rate of population. For these reasons the environmentally stimulated increase in energy inputs would be partially or wholly offset.
>
> "Consideration was given to the shifting nature of our transportation system. Evidence indicates a shift from the less energy intensive modes (i.e. railroads and barges) to the more energy intensive modes (such as airlines). This was factored into the forecast." [25, pp. 27-28]

The rationale quoted above is portrayed well by the graphic display in Figure 17, in spite of the fact that it depicts another, similar set of projections. The Figure 17 projection of little to no change in the existing modal split (with the exception of an increasing shift to air modes) also coordinates with the projections made in earlier portions of this section with respect to urban traffic congestion.

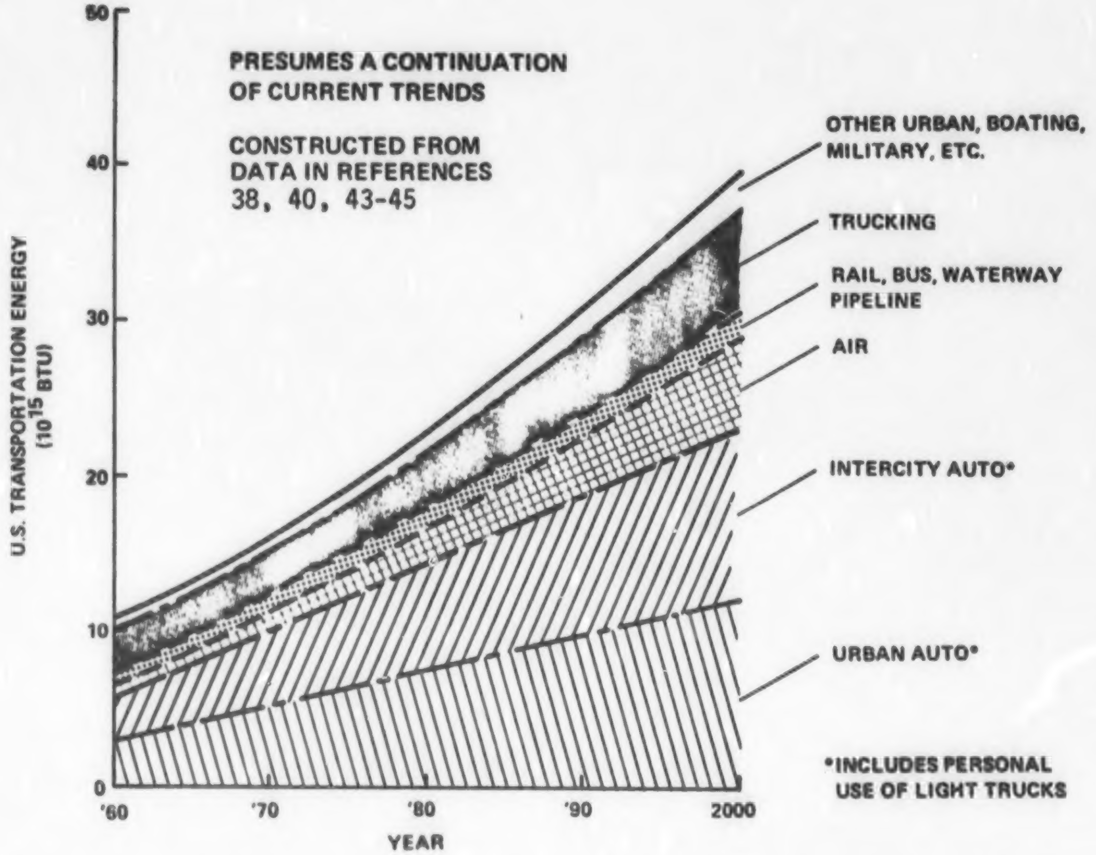


Figure 17. Projected U.S. transportation energy usage by mode, 1960-2000.

Source: Reference 42, p. 9.

Postulated sources of petroleum supply, based on a forecast need for petroleum which is somewhat larger than the energy consumption forecast of Table 30, are shown in Figure 18. Even though the total energy supply shown in Figure 18 is on the order of 15 percent higher than the base forecast selected in this study, a downward correction of Figure 18 by this amount still indicates an alarmingly great dependence on foreign sources for future petroleum supply. Some policy implications for the FEA in conjunction with the proposed goal of energy independence by 1980 are discussed in Section 4. Possible strategies suggested to achieve this goal are documented in Volume 1, Part II.

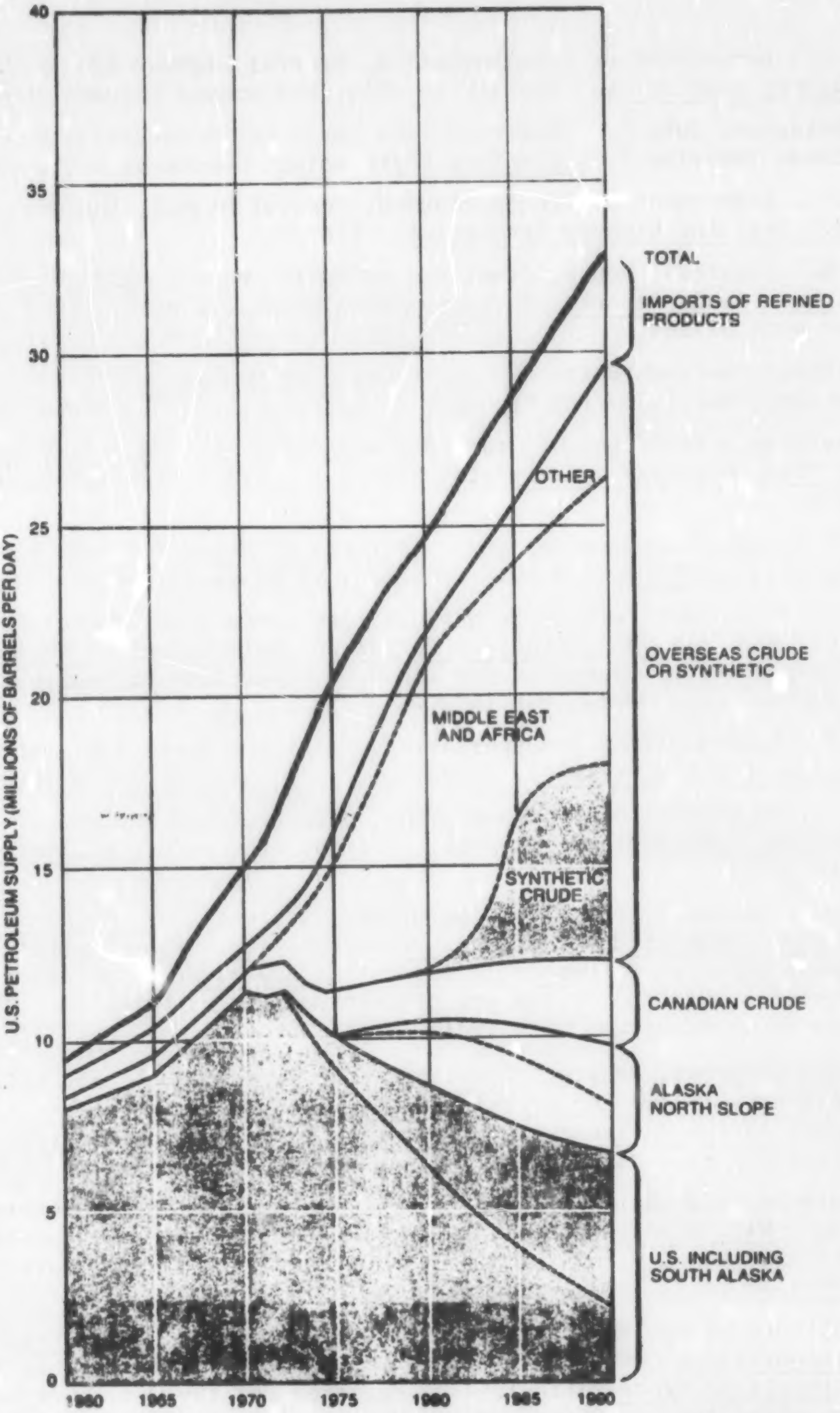


Figure 18. Projected U.S. dependence on overseas oil.

Source: Reference 46, p. 22. From "Energy Policy in the United States", by David J. Rose. Copyright © 1973 by Scientific American, Inc. All rights reserved.

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SECTION 3

CONGESTION AND AIR POLLUTION IN FOUR U.S. CITIES

The previous section provides an information base which can be used as a point of departure for preparing order-of-magnitude estimates on a national scale of the impacts of feasible tradeoffs between improving urban mobility, improving air quality, and reducing petroleum use by urban autos. This information is drawn on in the analysis elsewhere in this study of the pollutant emission and energy use impacts on a national scale of alternative modal mixes (see Volume 2, Section 2), and in the evaluation of specific actions which might be included in a joint interagency strategy (see Volume 1). Provision of similar information and its analysis for all principal urban areas in the United States, however, was considered to be outside the scope of the study. Nonetheless, it was felt to be meaningful in this volume to go through the exercise on a metropolitan level of identifying and describing air pollution and congestion conditions in four cities of mutual interest to UMTA and EPA. Energy use problems were not included since they are not usually subject to local control.

SELECTION OF URBAN REGIONS OF MUTUAL EPA/UMTA CONCERN

Table 32 summarizes the characteristics of the cities considered in the selection of urban regions of mutual EPA/UMTA concern. In order to select cities of greatest mutual concern, INTERPLAN first considered which cities were of particular interest to each agency. With respect to EPA, there are 29 Air Quality Control Regions (AQCRs) in the United States which cannot achieve the National Ambient Air Standard without transportation controls supplementary to the Federal Exhaust Emissions Control Program, a program aimed at replacing older vehicles with new automobiles which produce lower levels of pollution. EPA is now requiring the states involved to submit transportation control strategies for these areas, including not only programs for retrofit and inspection, but also plans for improving traffic flow, encouraging carpooling, expanding the use of public and para-transit, and imposing motor vehicle restraints.

Transportation control strategies of six of the 29 AQCRs of particular concern to EPA are to be proposed by the Administrator of EPA rather

Table 32. Summary of characteristics of cities under consideration in the selection of urban regions of mutual EPA/UMTA concern.

STATE	REGION	MUST SUBMIT TRANSPORTATION CONTROL STRATEGIES			UMTA-RD&D TRANSIT INTEGRATION		UMTA-EPA AREAS OF MUTUAL CONCERN
		All	Special* Concern	Promulgated By EPA Adm.	Major Significance	Significant	
Alaska	Northern Alaska	X					
Arizona	Phoenix-Tucson	X	X	X			
Calif.	Metro. Los Angeles	X	X	X		X	X
	San Francisco Bay	X			X		
	San Joaquin Valley	X		X			
	San Diego					X	
	Sacramento	X					
Colo.	Metropolitan Denver	X	X				
Conn.	(See N.Y.)						
D.C.	National Capital (Interstate-Md.)	X					
Fla.	Miami					X	
Ill.	Metro. Chicago (Interstate-Ind.)	X					
La.	New Orleans					X	
Md.	Metro. Baltimore (Nat. Capital - See D.C.)	X	X			X	X
Mass.	Metropolitan Boston	X	X				
Minn.	Minneapolis-St. Paul	X	X				
N.J.	(See N.Y.)						
N.M.	El Paso-Las Cruzes-Alamagordo (Interstate - Texas)	X		X			
N.Y.	N.J.-N.Y.-Conn. Interstate	X	X				

*Studied in Reference 1.

Table 32. (continued)

STATE	REGION	MUST SUBMIT TRANSPORTATION CONTROL STRATEGIES			UMTA-RD&D TRANSIT INTEGRATION		UMTA-EPA AREAS OF MUTUAL CONCERN
		All	Special* Concern	Promulgated By EPA Adm.	Major Significance	Significant	
Nev.	Northwest Nevada	X		X			
	Nevada	X		X			
Ohio	Metropolitan Dayton	X	X				
	Cleveland					X	
Oregon	Portland (Interstate-Wash.)	X					
Pa.	Metropolitan Philadelphia	X	X		X		X
	Southwest Pennsylvania	X					
	Pittsburgh	X	X				
Texas	Corpus Christi-Victoria	X					
	Metropolitan Houston-Galveston	X	X				
	Austin-Waco	X					
	Metropolitan Dallas-Ft. Worth (El Paso, etc. - see N.M.)	X					
Utah	Wasatch Front (S.L. City)	X	X				
Wash.	E.Wash.-N.Idaho Interstate-Spokane)	X	X				
	Puget Sound Interstate-Seattle)	X	X		X		X

*Studied in Reference 1.

than by state agencies. Also EPA recently published detailed transportation strategies for 14 major metropolitan areas of particular interest to EPA. Since two of the areas studied—Phoenix and Los Angeles—coincide with two of the six AQCRs mentioned above, these cities are considered to be of especially strong interest to EPA.

Regarding urban areas of special concern to UMTA, INTERPLAN's "Integration of Transit Systems" report, prepared for UMTA (2), identified three urban areas—Seattle, San Francisco and Philadelphia—with significant immediate potential for transit demonstrations, and studied them in great detail. Six additional areas were selected for both field investigation and research. These six areas, while showing a lesser degree of potential for demonstrations in transit integration, still showed especially strong potential for improved transit use. Therefore, these nine urban areas were considered to be of particular interest to UMTA.

The coincidence of EPA and UMTA areas of interest can be found by examining in Table 32 the characteristics of the 18 areas of particular EPA interest (the 14 major metropolitan areas plus the AQCRs whose transportation control strategies will be prepared by EPA) along with the nine areas of particular interest to UMTA. Of the four cities proposed as the subjects of this volume, Seattle and Philadelphia are among the three urban areas of significant immediate potential to UMTA as well as being included in EPA's study of 14 major metropolitan areas (1). Los Angeles is one of the two cities of prime importance to EPA as well as being one of the six areas of strong interest to UMTA. Baltimore is both one of EPA's 14 major metropolitan areas and UMTA's six areas of strong interest.

The four cities and their transportation regions provide a broad spectrum of problems and resources that might be used to alleviate these problems. They exhibit different degrees of traffic congestion, air pollution, dependence on the automobile, and adequacy of public transportation. Public concern over these problems is high in all regions, but there is a wide divergence in the degree to which action programs have been drawn up and are being pursued. Seattle, for example, has already turned its public transit operations over to a single metropolitan government, while Los Angeles is still debating the relative merits of rail rapid transit and extended bus service. Two of the regions have old central cities typical of the East Coast, while two represent cities which have typically grown from the extensive use of the private automobile. Population within the census-designated Standard Metropolitan Statistical Area (SMSA) is over one million in all cases, but the cities themselves offer a range of population sizes.

Table 33 presents some of the basic characteristics of the four cities for which detailed information is presented in the remaining portion of this section.

Table 33. Selected characteristics of proposed study regions.

Region	SMSA Population (1,000's)	Geographical Location	Extent of Local Action for Mass Transit	Intensity of Problems
Los Angeles	7,032	Southwest	Minimal	High
Philadelphia	4,200	Northeast	Average	High
Baltimore	2,071	Mideast	Average	Above Average
Seattle	1,422	Northwest	High	Average

Further background data on vehicle populations, highway characteristics, and modal split in the four cities is collected in Appendix E.

LOS ANGELES

Introduction

The acquisition of information on congestion, air pollution and energy consumption in Los Angeles was a time-consuming task, because a number of political and planning regions exist in the area, each with a different geographical boundary and a different set of data and statistics. For example, the region of relevance with respect to air pollution is the South Coast Air Basin (SCAB). The geographical boundaries of the basin follow a high mountain ridge from Point Arguello along the Pacific Coast to the San Jacinto Wilderness area just northeast of San Clemente. The 8,680 square miles of the basin include all of Ventura and Orange Counties and the most populated parts of Santa Barbara, Los Angeles, San Bernardino and Riverside Counties. Much of the information relevant to congestion and transportation-related energy usage (i.e., highway travel), however, is available only for the similarly-sized, but geographically different Los Angeles Region Transportation Study (LARTS) area which overlaps almost all of the SCAB with the exception of Santa Barbara County. Other useful information is also available for the Southern California Association of Governments (SCAG) which covers the 38,528 square mile, six county area of Ventura, Los Angeles, San Bernardino, Orange, Riverside and Imperial Counties. The geographical correspondence among these regions is shown in Figure 19.

Although the area encompassed by these regions differs greatly in some cases, there is little difference among them in the statistical base of interest in this study, as shown in Table 34. Since relevant information is also available on a county basis, comparative data is also given in Table 34 for the five counties frequently used to typify the Los Angeles area: Los Angeles, Orange, Ventura, Riverside, and San Bernardino. Inasmuch as all the information in the required statistical base was not available from a single planning region, and in view of their slight differences, the information in the ensuing text on Los Angeles may refer interchangeably to data pertaining to one or more of them.

Current Status and Future Trends in Congestion

CURRENT STATUS. As in most major cities in the U.S., congested conditions are typically encountered in Los Angeles on freeways and principal arterials during morning and afternoon peak traffic volumes. As shown in Figure 2 (Section 2), however, the peak number of vehicle-miles traveled in Los Angeles tends to represent a smaller percentage of the total vehicle-miles traveled than is typical for cities of this size, and the period of peak travel is of longer duration. Like other urban areas, the bulk of minor arterials, collectors and local streets tend to be less affected by peak-hour congestion (see Table 10, Section 2). As suggested by the nationwide statistics presented in Section 2, not all major arterials in Los

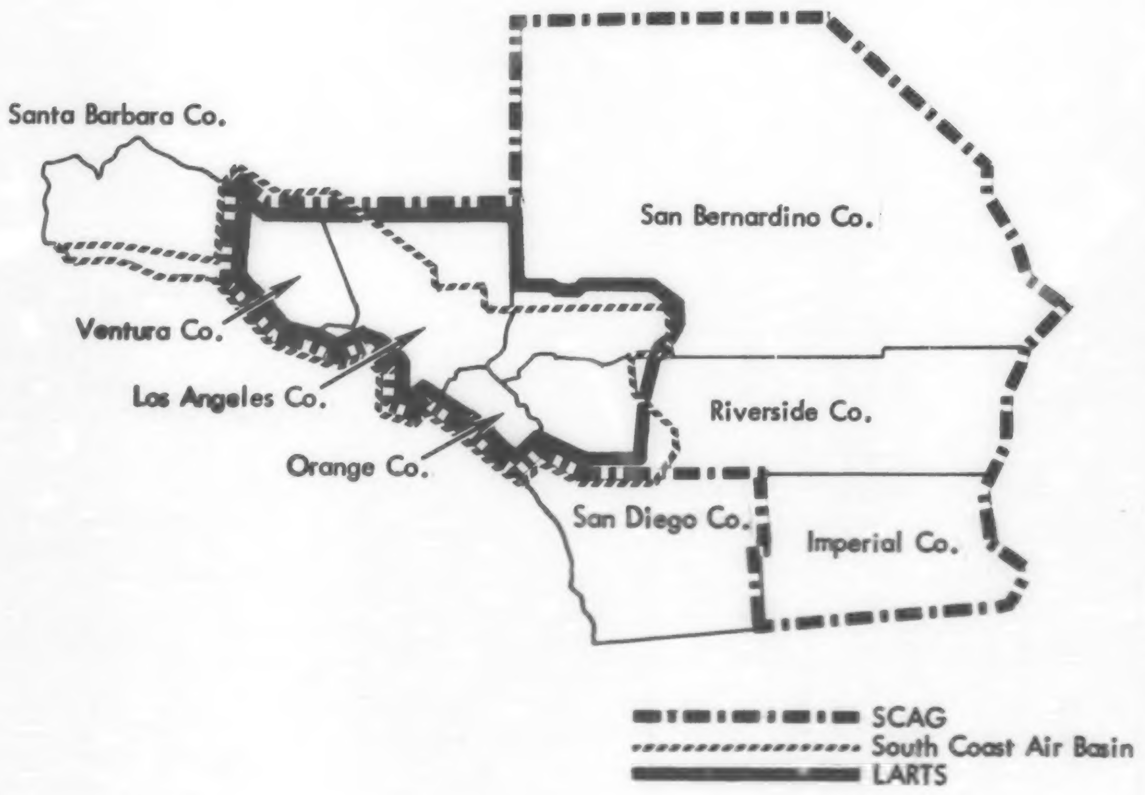


Figure 19. Geographical boundaries of various planning regions in Los Angeles.

Table 34. Comparative statistics and travel projections in planning regions in the Los Angeles area.

	1970	1975	1977	1980	1990	2000
Population (Millions						
South Coast Air Basin [3, 5][+]	9.72			11.46		
SCAG 90 (Series D) [6]	10.044			11.63	13.90	16.06
SCAG (Series E) [6]	10.044			10.95	11.93	12.71
LARTS [5]				11.28		
Five Counties [3, 4]	9.99	10.64	11.03	11.62	12.8	16.0*
Five Counties [3]	10.06	11.32		12.75		
Week Day Vehicle Miles Traveled (Million VMT/Day)						
South Coast Air Basin [5]			168.85			
LARTS [4]	145.	166.	169.8	180.5	220.	258.*
LARTS [3]			167.63	180.14		
Motor Vehicle Registrations (Millions)						
South Coast Air Basin [3]	6.3	7.5	7.9	8.8	11.8	15.4*
Five Counties [4]	6.28	7.45	7.87	8.75	11.5*	14.0*

[+] Sources given in brackets.

*Extrapolation.

Angeles are congested at peak travel periods. For example, Table 35 shows a few of these which in 1972 were estimated to have excess capacities at peak travel hours of from 19 to 50 percent.

The severest congestion in Los Angeles occurs on the freeway system. Figures 20-23* show congested sections of the system as they appeared in 1967. The "hot-spots" in the system are graphically illustrated in these maps and demonstrate well the highly localized nature of the urban traffic congestion problem. Currently, the largest congested portion of the freeway system is the 42-mile loop of the San Diego, Santa Monica and Harbor Freeways. This loop, shown in Figure 24, now carries an estimated 4.8 percent of the total vehicle-miles and 13.6 percent of the total freeway vehicle-miles traveled in the South Coast Air Basin.

Los Angeles traffic engineers tend to consider that most of the freeway vehicle-miles traveled in the heavy direction of traffic flow are subjected to congested conditions** during peak hours. The proportion of the total vehicle-miles traveled which is subjected to these congested conditions can be estimated by first noting that the freeway system accounts for about 35 percent of the total vehicle-miles traveled in the area. Of this, 30 to 42 percent occurs during peak periods, so that 10 to 15 percent (.35 × .30 — .35 × .42) of the total vehicle-miles traveled occurs on freeways during peak travel periods. With 55 to 60 percent of the total traffic flowing in the heavy direction during peak hours, as is characteristic of the area, some 6 to 9 percent (.55 × .10 — .60 × .15) of the total vehicle-miles traveled on freeways in Los Angeles is subjected to congested conditions daily. Travel in offpeak hours is also subjected to some degree of congestion, since, during at least three of the offpeak hours, the freeways

---

*Grateful acknowledgement is due Mr. Bob Blythe, of the California Division of Highways, District 7, Advanced Planning, Los Angeles, who provided INTERPLAN with these maps.

**That is, at least Level D (see Table 8, Section 2), which represents an operating freeway speed range of 40 to 50 m.p.h. and approaches unstable flow. The 1971 Travel Time Study for Los Angeles done by the California Division of Highways computed the average speed on the freeways at the most congested time periods at 36 m.p.h. with an 18 to 50 m.p.h. range. The most heavily used parts of the system average 33.4 m.p.h. in the morning and 29.8 m.p.h. in the afternoon peak hour. The offpeak average was 57.2 m.p.h.

[Text continues on p. 90]

Table 35. Current volumes and capacities on selected arterials in the Los Angeles area.

Location[a]	Morning Peak-Hour Volume (vehicles per hour)	Capacity[b] (vehicles per hour)	Excess[c] Capacity
Washington Blvd. @ Western Ave.	933	1200	29%
Figueroa St. @ Slausen Ave.	1527	1800	19%
Ventura Blvd. @ Van Nuys Blvd.	1006	1200	20%
Sunset Blvd. @ Alvarado St.	1197	1800	50%

a -- sites selected are all major arterials which parallel existing freeways.

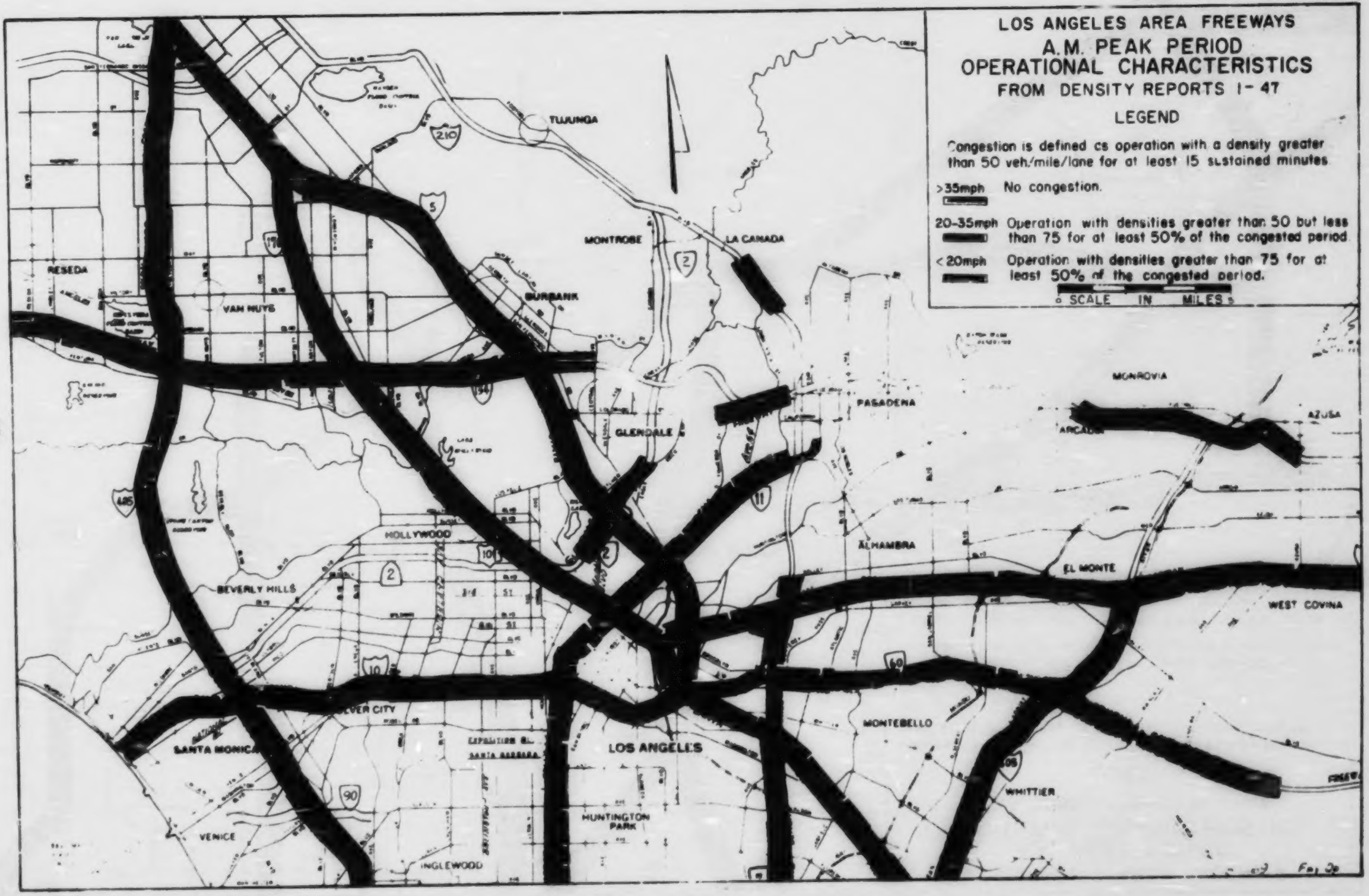
b -- based on an estimated capacity of 600 vehicles per lane per hour for urban arterials.

c -- computed as the difference between observed volumes and capacity as a percentage of observed demand.

Reproduced from Reference 3.

(Source cited in Reference 3: City of Los Angeles Traffic Department, 1972 Traffic Counts.)

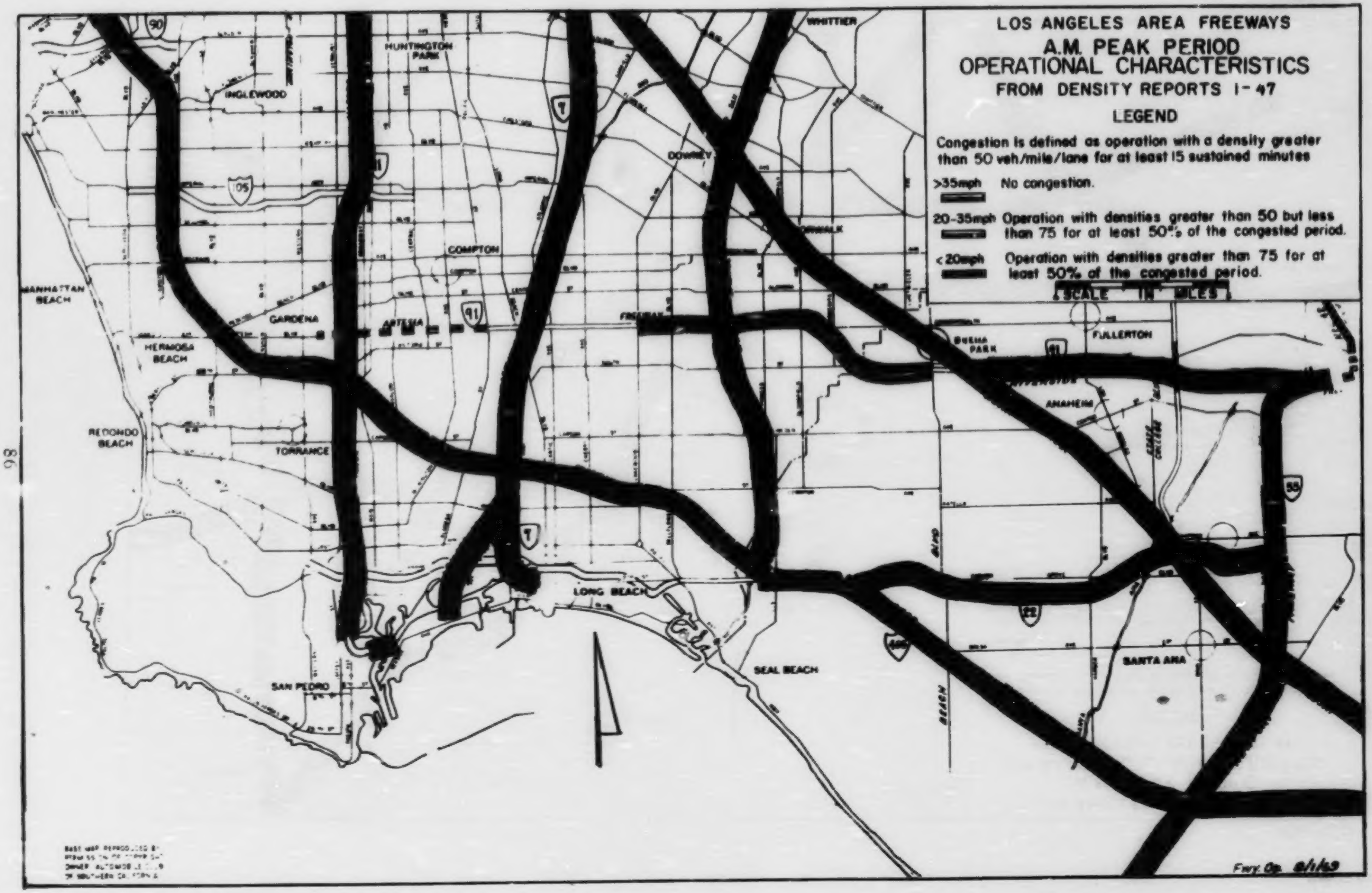
FIGURE 20



LOS ANGELES AREA FREEWAYS
A.M. PEAK PERIOD
OPERATIONAL CHARACTERISTICS
FROM DENSITY REPORTS 1-47

LEGEND
Congestion is defined as operation with a density greater than 50 veh./mile/lane for at least 15 sustained minutes.
>35mph No congestion.
20-35mph Operation with densities greater than 50 but less than 75 for at least 50% of the congested period.
<20mph Operation with densities greater than 75 for at least 50% of the congested period.
SCALE IN MILES
0
5
TUJUNGA
210
5
MONTROSE
LA CANADA
2
RESEDA
VAN NUYS
BURBANK
134
GLENDALE
PASADENA
MONROVIA
ARCADIA
AZUSA
11
405
HOLLYWOOD
101
2
ALHAMBRA
EL MONTE
WEST COVINA
BEVERLY HILLS
10
60
CULVER CITY
SANTA MONICA
LOS ANGELES
MONTEBELLO
90
605
WHITTIER
HUNTINGTON PARK
VENICE
INGLEWOOD

FIGURE 21

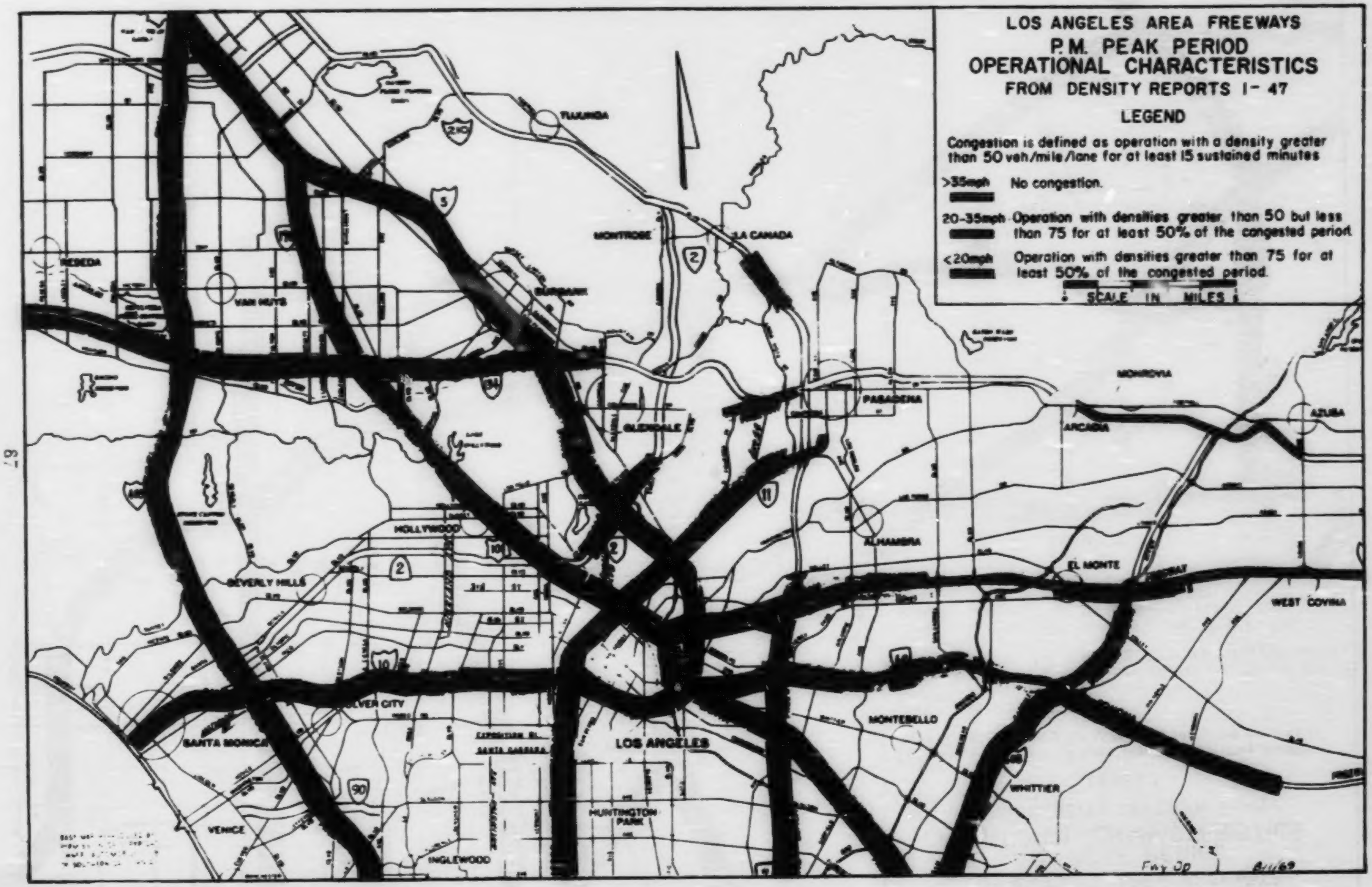


LOS ANGELES AREA FREEWAYS
A.M. PEAK PERIOD
OPERATIONAL CHARACTERISTICS
FROM DENSITY REPORTS 1-47

LEGEND

Congestion is defined as operation with a density greater than 50 veh/mile/lane for at least 15 sustained minutes

FIGURE 22



LOS ANGELES AREA FREEWAYS
P.M. PEAK PERIOD
OPERATIONAL CHARACTERISTICS
FROM DENSITY REPORTS 1 - 47

LEGEND

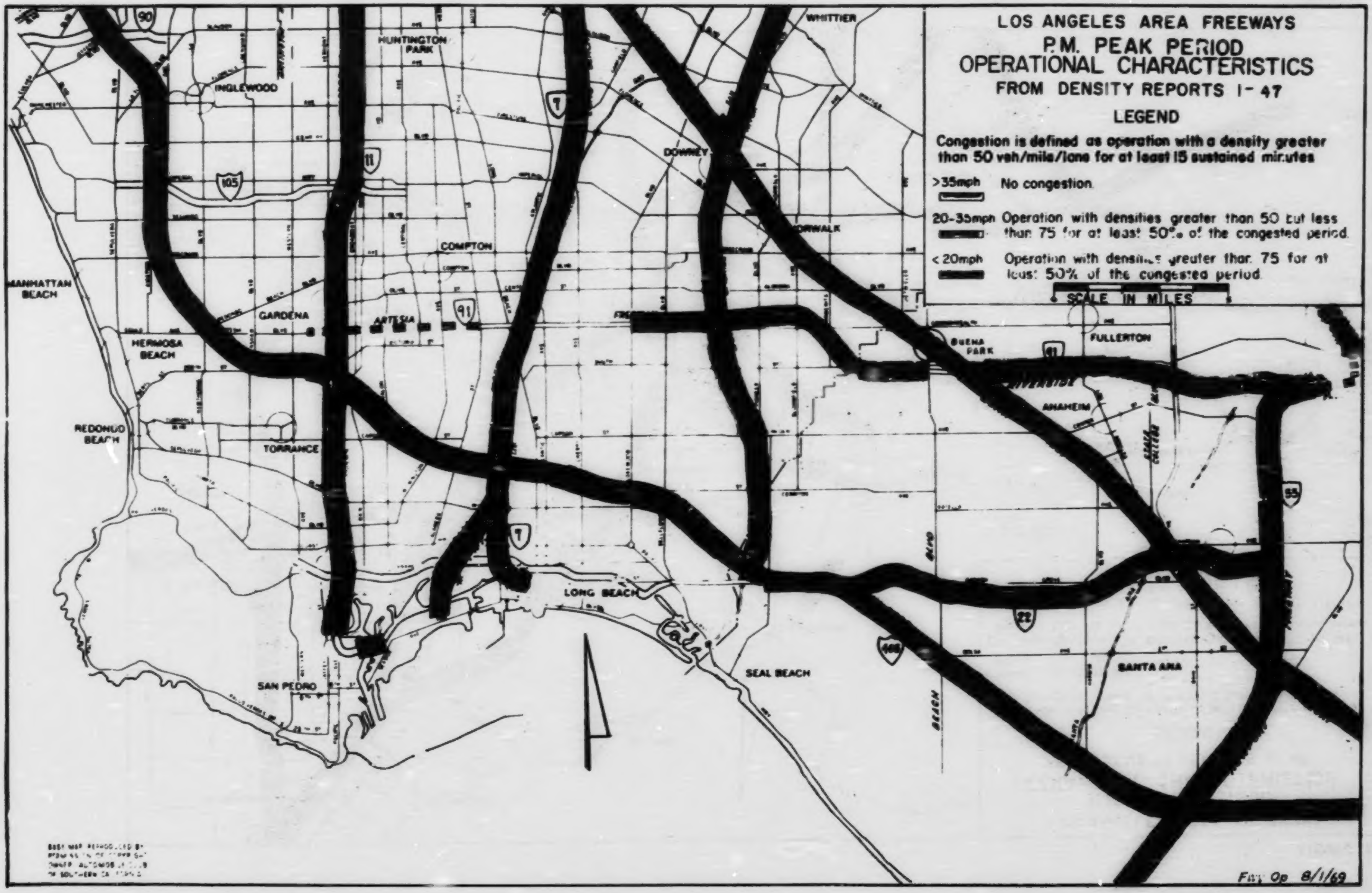
Congestion is defined as operation with a density greater than 50 veh/mile/lane for at least 15 sustained minutes

>35mph ▬	No congestion.
20-35mph ▬	Operation with densities greater than 50 but less than 75 for at least 50% of the congested period.
<20mph ▬	Operation with densities greater than 75 for at least 50% of the congested period.

SCALE IN MILES

Fwy Op 8/1/69

FIGURE 23



LOS ANGELES AREA FREEWAYS
P.M. PEAK PERIOD
OPERATIONAL CHARACTERISTICS
FROM DENSITY REPORTS 1-47

LEGEND

Congestion is defined as operation with a density greater than 50 veh/mile/lane for at least 15 sustained minutes

>35mph	▭	No congestion.
20-35mph	▬	Operation with densities greater than 50 but less than 75 for at least 50% of the congested period.
<20mph	■	Operation with densities greater than 75 for at least 50% of the congested period

SCALE IN MILES

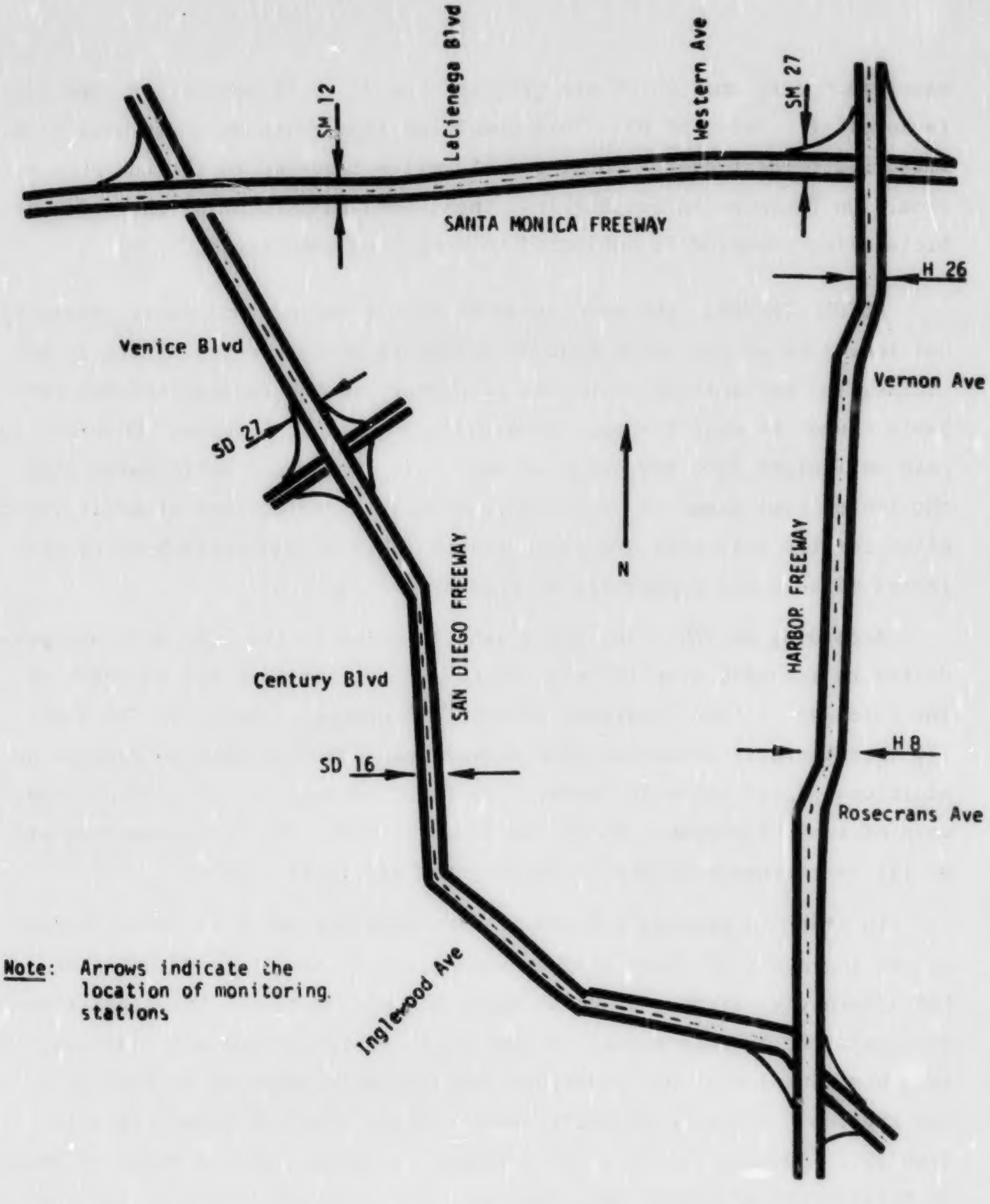


Figure 24. The Los Angeles freeway 42-mile loop.

Reproduced from Reference 3.

(Source cited in Reference 3: California State Division of Highways.)

bear traffic volumes which are greater than 72 to 75 percent of capacity (a level of service of D). This condition represents an additional estimated 2.2 percent of the total vehicle-miles traveled in the Los Angeles area. On freeways in Los Angeles, then, some 10 percent of the total vehicle-miles traveled is subjected to congested conditions.

FUTURE TRENDS. The prediction of travel volumes and their geographical locations on any urban roadway system is an inherently difficult exercise, and reliable descriptions of changes in the roadway network probably cannot be made for more than the ensuing 3 to 5 years. However, to gain an insight into the order of magnitude of changes anticipated over the longer time frame of this study, available projections of daily vehicle-miles for the SCAG area are presented in Table 36 and corresponding projected mileage and capacities of roadways in Table 37.

According to Table 36, daily vehicle-miles in the SCAG area are predicted to increase from 151 million to 218 million over the 18 years of the forecast, a total increase of about 30 percent. According to Table 37, this increase in anticipated travel demand is forecast to require an additional 3,554 miles in roadways, a total average increase in all roadways of some 14 percent, which, as shown in Table 37, is represented primarily by increases in the freeway system and local streets.

In order to provide a frame of reference for possible future comparison of the costs of these roadway extensions to the costs of UMTA/EPA/FEA alternative strategies which might be applied to the Los Angeles area, the projected average annual increments in vehicle-miles was computed, and the incremental cost per additional vehicle-mile, derived in Section 2, was applied. A change in daily vehicle-miles of 67 million (218 — 151) from 1972-1990 represents a total change in annual vehicle-miles of about 25 billion (67 million × 365) and, over the forecast 18 years, is equal to an average annual incremental change of 1,360 million vehicle-miles per year (25 billion ÷ 18). Now, using an average annual incremental cost per vehicle-mile of $0.018, an annual incremental cost of about $24.5 million is implied (1,360 million × 0.018). The cumulative incremental cost for

Table 36. Future trends in daily vehicle-miles on roadways in the SCAG area, classified functionally and by design type.

Classification	1972	1980	1990
	(millions of vehicle-miles)		
Functional:			
Interstate	30	33	37
Other principal arterials	64	81	105
Minor arterials	33	37	40
Collectors	10	13	16
Local streets	14	16	20
Total	151	180	218
Design type:			
Access controlled	53	63	79
Four or more lanes, no access control	41	52	67
Less than 4 lanes, excluding local	43	48	53
Total	137	164	199

Source: Reference 7.

Table 37. Future trends in mileage of roadways required to meet forecast increases in travel demand in the SCAG area.

Classification	Percent Increase (1972-90)	Miles		
		1972	1980	1990
Functional:				
Interstate	20	300	344	360
Other principal arterials	6	2,880	2,924	3,067
Minor arterials	5	3,541	3,634	3,716
Collectors	7	2,567	2,700	2,758
Local streets	14	16,234	17,284	19,175
Total	14	25,522	26,886	29,076
Design type:				
Access controlled		637	722	917
Four or more lanes, no access control		2,644	2,970	3,144
Less than 4 lanes, excluding local		6,007	5,960	5,840
Total		9,288	9,652	9,901

Source: Reference 7.

increases in vehicle-miles over the next 20 years then becomes $4.7 billion (see page 33, Section 2, for sample calculations).

If this calculation is performed using the estimated incremental cost for new urban roadway construction and rights-of-way of $0.0087, derived in Section 2, the average annual incremental cost becomes $12 million (1,360 million × 0.0087). The result is a 20-year cumulative cost of $2.25 billion, which represents the estimated sum required solely for new roadway construction and rights-of-way in Los Angeles over the next 20 years to accommodate anticipated increases in travel of some 28 billion vehicle-miles. This value of $2.25 billion, then, provides a basis for comparing the projected investment costs for alternative strategies designed to reduce congestion, air pollution and energy use in the Los Angeles area in conjunction with their tradeoffs in terms of concomitant social benefits and costs.

Air Pollution

A 1970 inventory of emissions calculated by the California Air Resources Board indicated that a total of 16,600 tons of the five major pollutants—hydrocarbons, particulates, oxides of nitrogen (NO_x), sulfur dioxide, and carbon monoxide (CO)—were emitted each day in the South Coast Air Basin. Over 72 percent of these emissions were in the most populated part of Los Angeles County which is included both in the Air Basin and in LARTS. Another 13.5 percent is emitted within Orange County. The other counties follow with about 5 percent or less.

The pollutants of special interest in this study are highly reactive hydrocarbons (HC), NO_x and CO, which are the three major vehicle emissions. The inventory in Table 38 indicates that motor vehicles are responsible for 1,560 tons per day, or 87.1 percent of the highly reactive HC pollution; 1,180 tons/day, or 75.2 percent of the NO_x pollution; and 11,000 tons/day, or 97.5 percent of the CO pollution. Indeed, at least in the Los Angeles area, motor vehicles are responsible for the bulk of the air pollution problem.

Table 38. South Coast Air Basin emission inventory (1970).

Emission Source (Tons/Day)	Organic Gases Reactivity High	Organic Gases Reactivity Low	Organic Gases Total	Particulate Matter	Oxides of Nitrogen	Sulfur Dioxide	Carbon Monoxide
STATIONARY SOURCES							
PETROLEUM							
Production		114	114	0.4	27.9	5.5	
Refining	5.0	40.0	45.0	5.0	22.0	50.0	5.0
Marketing	68.1	79.5	148		11.0		
SUBTOTAL	73.1	234	307	5.4	60.9	55.5	5.0
ORGANIC SOLVENT USERS							
Surface Coating	49.2	201	250	15.0			
Dry Cleaning	6.1	26.1	32.2				
Degreasing	22.6	82.6	105				
Other	32.9	140	173	6.0		1.0	
SUBTOTAL	110	450	560	21.0		1.0	
CHEMICAL				0.5	0.2	115.0	
METALLERGICAL				21.3	3.0	32.9	3.0
MINERAL		1.0	1.0	26.5	5.5	0.8	
INCINERATION							
Open Burning (dumps)	0.2	2.0	2.2	0.7	0.3	0.1	4.0
Open Burning (backyard)	1.2	13.0	14.2	4.7	2.3	0.2	34.4
Incinerators		1.2	1.2	1.2	1.2		1.3
Other	0.5	4.3	4.8	10.2	2.4		30.0
SUBTOTAL	1.9	20.5	22.4	16.8	6.2	0.3	69.7

Reproduced from Reference 3, p. A-3.

Table 38. (continued)

Emission Source	Organic Gases			Particulate Matter	Oxides of Nitrogen	Sulfur Dioxide	Carbon Monoxide
	Reactivity						
	High	Low	Total				
COMBUSTION OF FUELS							
Steam Power Plants	0.2	6.8	7.0	7.8	135	40.9	
Other Industrial	0.1	6.7	6.8	9.8	88.8	9.5	1.1
Domestic and Commercial	0.2	0.2	0.4	9.8	60.1	0.6	0.4
SUBTOTAL	0.5	13.7	14.2	27.4	284	51.0	1.5
AGRICULTURE							
Debris Burning	0.9	7.1	8.0	4.6	0.5		24.1
Orchard Heaters		5.0	5.0	3.8		1.6	
Agricultural Product Processing Plants	8.9	0.5	9.4	0.9			
SUBTOTAL	9.8	12.6	22.4	9.3	0.5	1.6	24.1
TOTAL STATIONARY SOURCES	195	732	927	128	360	258	103
MOBILE SOURCES							
MOTOR VEHICLES							
Gasoline Powered							
Exhaust	1200	401	1600	62.4	951	34.9	10,800
Blowby	51.3	16.9	68.2				
Evaporation	360	154	460				
Diesel Powered		51.7	51.7	16.8	229	16.8	218
SUBTOTAL	1560	623	2180	79.2	1180	51.7	11,000
AIRCRAFT							
Jet Driven	21.7	36.6	58.3	23.8	13.1	3.0	44.1
Piston Driven	11.3	16.3	27.6	0.2	7.3	1.0	155
SUBTOTAL	33.0	52.9	85.9	24.0	20.4	4.0	199
SHIPS AND RAILROADS		5.4	5.4	3.6	6.2	1.1	9.2
TOTAL MOBILE SOURCE	1590	681	2270	107	1210	56.9	11,200
GRAND TOTAL	1790	1410	3200	235	1570	315	11,300

Reproduced from Reference 3, p. A-4.

Based on a correlation of monitored air pollution concentrations and calculated air emission inventories, the EPA and the California Air Resources Board have set goals for maximum total allowable emissions from all sources in the South Coast Air Basin. Currently these goals are:

Highly reactive HC :	161 tons/day
NO_x:	835 tons/day
CO :	2,481 tons/day.

The highly reactive HC emission rate indicates pollution due to photochemical oxidants. It has been estimated that about 80 percent of the unburned HC emitted by motor vehicle exhausts and 67 percent of the HC vented through the crankcase and evaporated from the fuel system and filling stations belong in the highly reactive category. These percentages have been used in the following calculations to relate highly reactive HC emissions to the California Air Resources Board and EPA HC emission standards for exhaust, crankcase, and evaporative emissions. Table F-1 in Appendix F lists these standards, as well as CO and NO_x standards, as they apply to vehicles sold in California for the particular model year in question. Standards previously slated for the 1975 model year have been postponed by the EPA administrator until 1976. This postponement is reflected in Table F-1 and all ensuing calculations.

CALCULATION OF EMISSION FACTORS. Emission control standards have been established separately for heavy duty vehicles (6,000 lbs. and over). Private automobiles are included in the category of light duty vehicles, along with taxis, pickups, and vans. Average vehicle-mile emission factors for the vehicle populations during specific years have been calculated by INTERPLAN to use in a rollback model estimation procedure for the Los Angeles area. These factors reflect the model year distribution in the population, the amount of travel typically associated with each, the age of each model, and the deterioration of emission controls with age. The standards were used as a rough estimate of a new vehicle's emission characteristics on the assumed generalization that maximum control specifications tend to set the goal for minimum performance design specifications. The deterioration factors used were comparable to those used in

Reference 8, including the assumption that catalytic mufflers on the 1976 and later models would be recharged every 25,000 miles or so. Table F-2 shows the calculated average emission factors for light duty vehicles.

A composite vehicle-mile emission factor can also be determined by appropriate weighting of light duty and heavy duty vehicle factors by the respective amount of vehicle miles traveled (VMT). By using a 1970 South Coast Air Basin vehicle population estimate of 5.6×10^6 light duty vehicles and 0.24×10^6 heavy duty vehicles and estimated yearly mileage driven per vehicle of 8,200 and 10,500 miles respectively, it was determined that approximately 5.2 percent of VMT can be attributed to heavy duty vehicles. The average vehicle-mile emission factors for a composite fleet of light and heavy duty vehicles based on this distribution are presented in Table F-3.

The factors have been calculated for two possible cases. The first, Case A, is the current motor vehicle control program which includes the imposition of the strict emission controls planned for 1975-76 in the 1976 model year. There have been objections raised to these 1976 controls as (a) being more strict than necessary, (b) not being technologically feasible for many of the tried and tested engines in production today, and (c) requiring too great a penalty in fuel economy. Though these objections may have some merit, it is quite unlikely that, if the correct tradeoffs are made with considerations of public health and the economic costs of air pollution, the 1976 standards will be completely revoked. However, they may be modified on the basis of new data when it becomes available. As an upper limit on such a possibility, a second case, Case B, is developed in these calculations. Essentially, Case B assumes that currently active control standards will be continued indefinitely, that is to say, that the 1976 standards will not be implemented.

TOTAL EMISSIONS FOR THE SOUTH COAST AIR BASIN. This study is primarily concerned with personal transportation. We have treated private personal travel in the Los Angeles area as being synonymous with light duty vehicle trips. According to the 1967 LARTS Base Year Study data, about 87.5 percent of vehicle trips in the Los Angeles area are made by auto, about 0.2 percent by taxis, and about 6 percent by pickup trucks, many of which may be carrying no cargo. Heavy duty trucks account for over 4 percent, and public and school buses for about 0.2 percent of the vehicle trips. Thus emissions by all light duty vehicles provide a reasonable estimate of the emissions by private personal transportation in Los Angeles. Estimates of these emissions are given in Table 39 and graphically illustrated in Figures 25, 26, and 27. Table 40 shows an estimate of total emissions by ground transportation for 1980 and 1990 and the share contributed by light duty vehicles.

Table 39. Estimated and projected weekday emissions from private personal travel in the Los Angeles area.

Year	CO	NO_2 (tons/day)	Total HC	Highly Reactive HC
1970	10504	1090	1767	1358
1972	8693	941	1393	1079
Case A:	1976 Control standards imposed as scheduled:			
1975	7015	669	1012	791
1977	4410	467	713	558
1980	2700	262	419	327
1985	1358	136	235	182
1990	1125	110	198	153
2000	1175	115	202	156
Case B:	Only currently active standards continued; 1976 controls not imposed:			
1975	7251	674	1036	810
1977	6396	536	915	719
1980	6591	434	831	656
1985	6979	403	843	669
1990	7515	418	900	714
2000	8816	484	1005	835

Figures 25, 26, and 27 show projections adapted from Reference 3 for total emissions from all sources for two cases: (1) no controls on motor vehicles, and (2) implementation of the current motor vehicle program. Case 2 is essentially equivalent to Case A above, except that the strict emission control standards are assumed to take effect in 1975 rather than 1976. Because of variations in assumptions used, there are likely to be

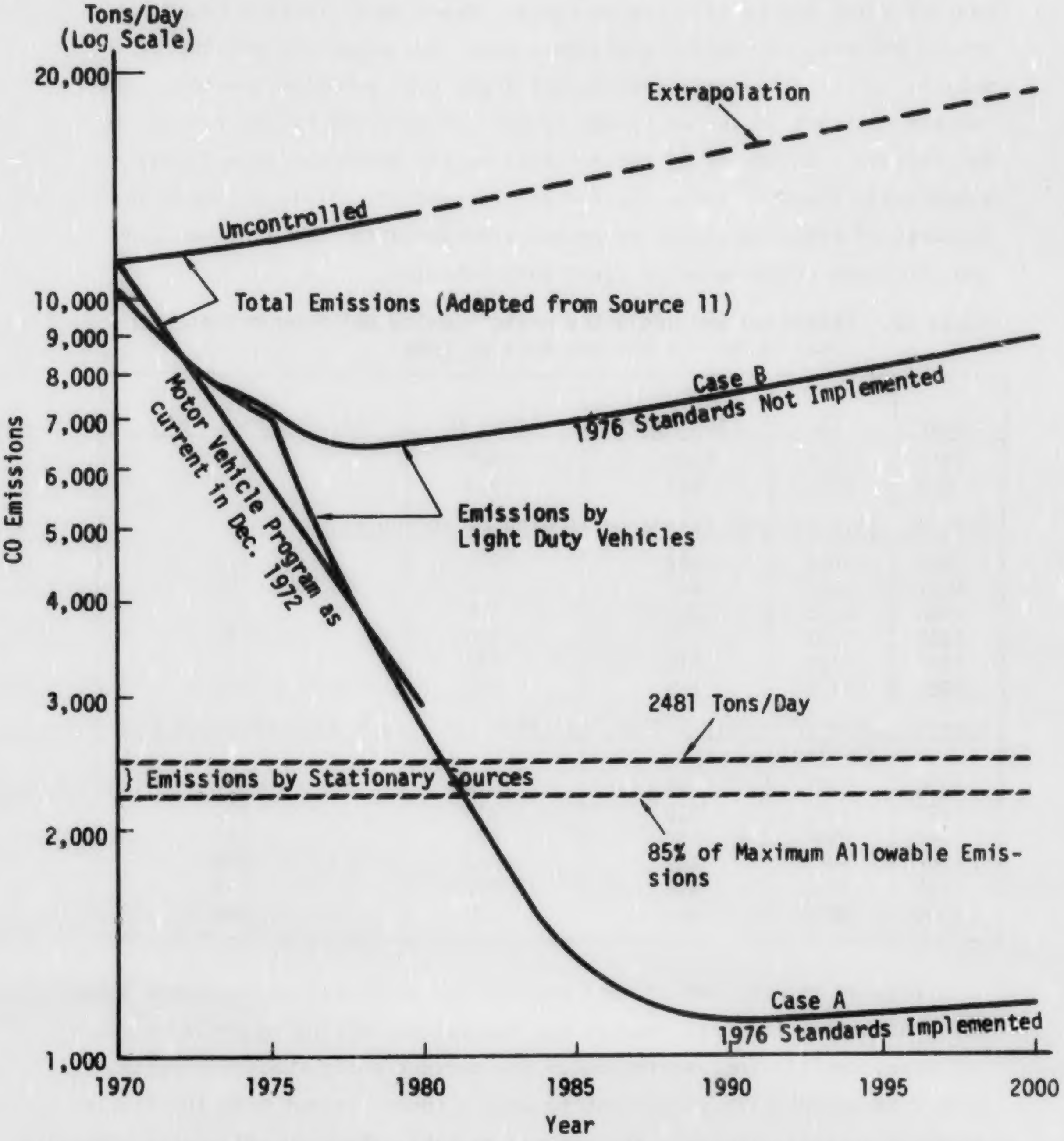


Figure 25. Estimates to the year 2000 of CO emissions for the South Coast Air Basin.

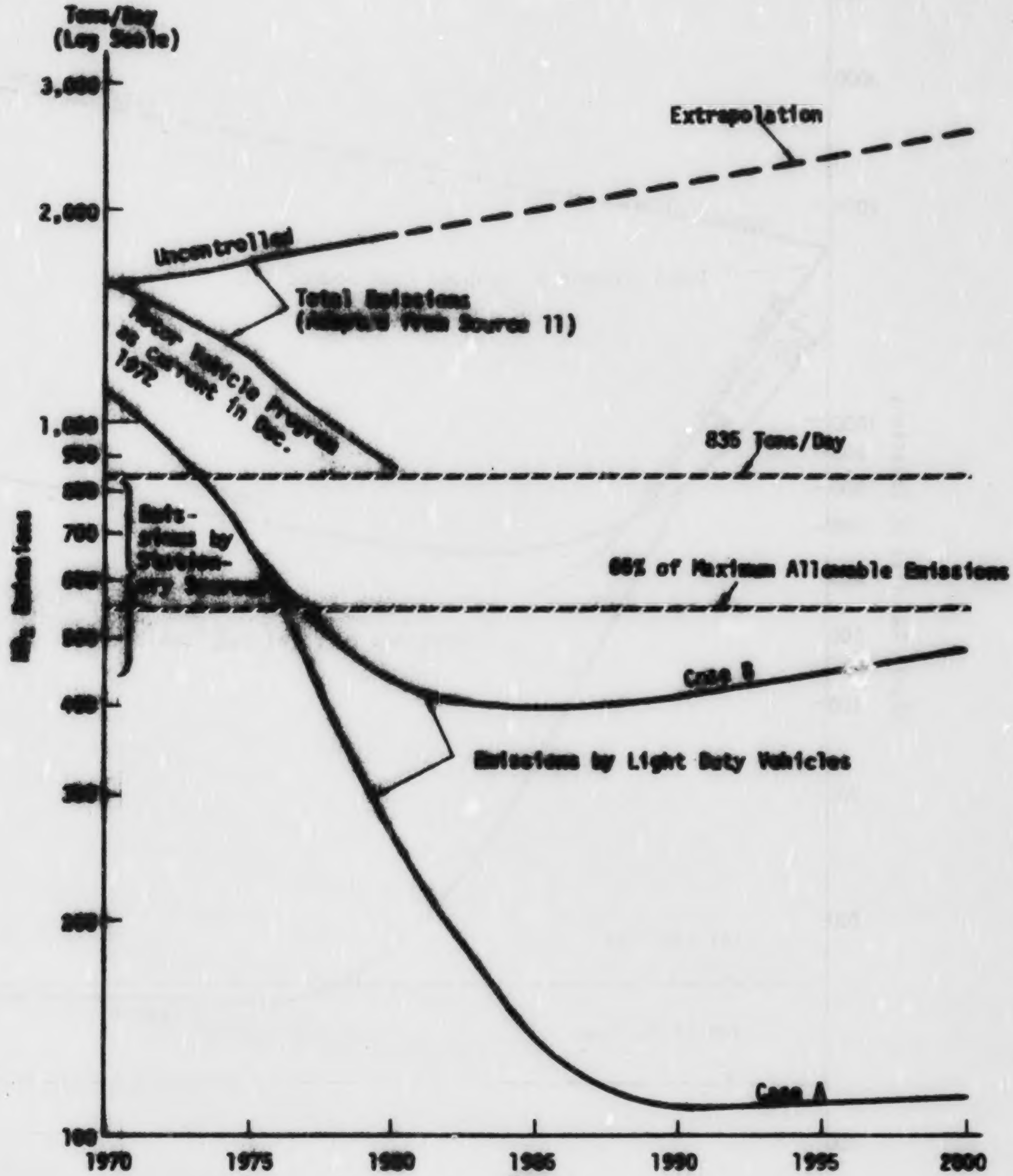


Figure 28. [illegible] to the year 2000 of NO_x emissions for the South Coast Air Basin.

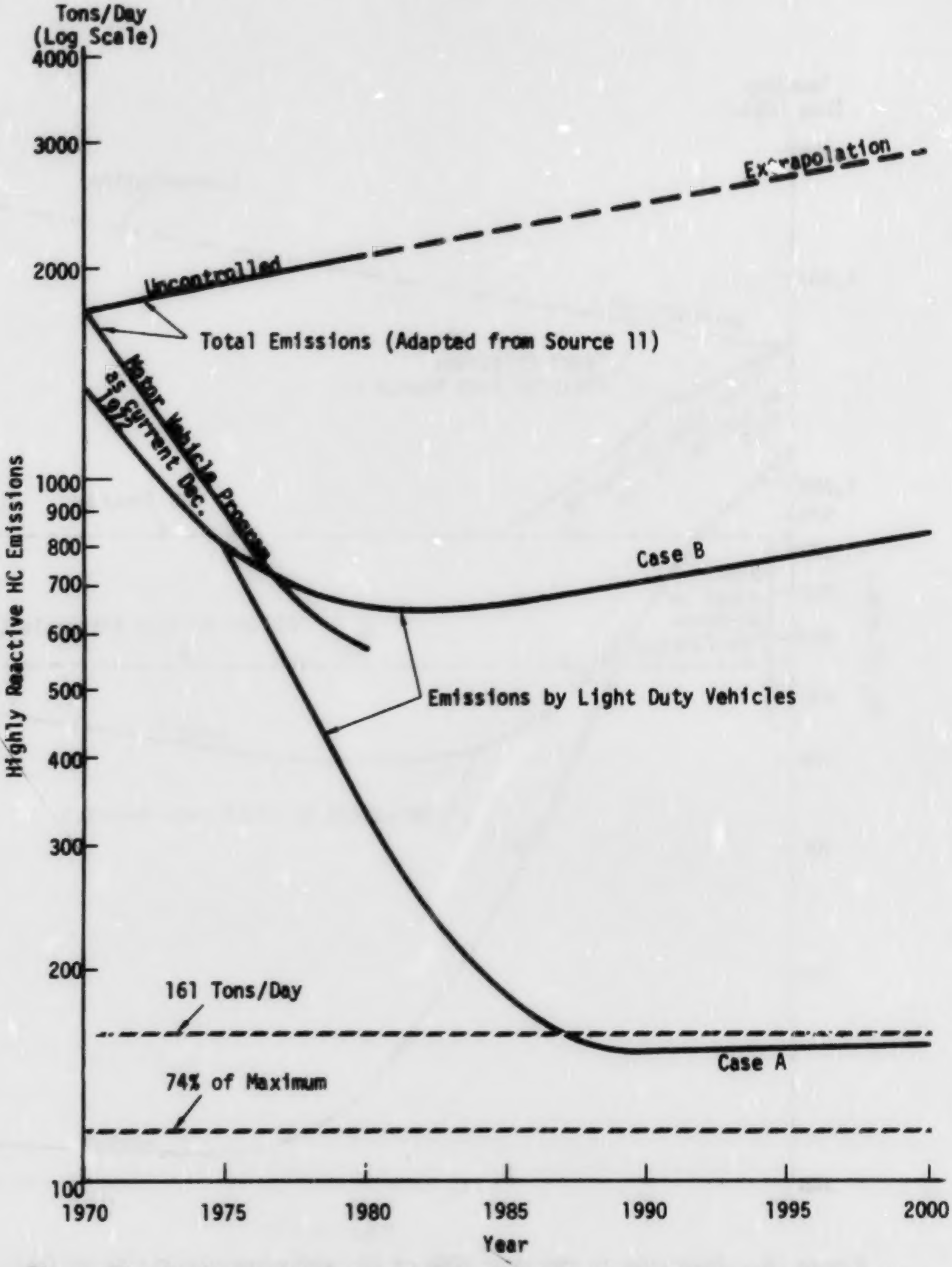


Figure 27. Estimates to the year 2000 of highly reactive HC emissions in the South Coast Air Basin.

Table 40. Case A[1] estimate of ground transportation emissions in Los Angeles and percent due to light duty vehicles.

	1980		1990	
	Total Emission (tons/day)	Percent due to LDV[2] (%)	Total Emission (tons/day)	Percent due to LDV (%)
CO	3,223	83.8	1,521	73.9
NO_x	329	79.8	155	70.7
HC	524	79.9	264	75.0
Highly Reactive HC	409	80.0	205	75.0

[1] Case A: 1976 emission standards maintained.
[2] LDV: autos, taxis, and pickups.
Note: Assumption that 5.2 percent of vehicle-miles traveled are due to heavy duty vehicles.

minor discrepancies in scale between the Case 1 curves and ones calculated for Case A. The trends, however, which are the primary concern of this exercise, do remain consistent. They indicate that if 1976 standards for CO and HC are not maintained, the air quality goals cannot be met even by private personal transportation, which is only one of several sources of pollutant emissions. An additional 20 to 25 percent of the emissions is generated by the rest of the ground transportation sector, not to speak of other sources listed in Table 38 which we do not consider.

The NO_x emission story can use further investigation. Besides mobile sources, the next most significant sources of nitrogen oxides for Los Angeles are the combustion of fuels for power generation, industrial, and domestic uses and for petroleum production and refining. The projected increases in these activities for the Los Angeles area as well as the practical effectiveness of current controls in limiting NO_x emissions will have a tremendous impact on whether any NO_x control standards can be relaxed. This question is beyond the scope of the study.

The methods used by INTERPLAN in calculating the above emissions were selected so that the results would be as consistent as possible with the total emission estimates provided in other current studies and with the goals for maximum daily emissions stated above. For example, no adjustments for speed were made as in the reference documents. Thus all the information presented in Figures 25, 26, and 27 is comparable. The estimated values may vary significantly from actual values, but the relative relationships should remain approximately the same. More accurate estimates would incorporate considerations of vehicle speeds, the effects of cold starts, and actual emission data for actual 1976 emission standard controls. The figures also show the maximum allowable emissions determined from the 1970 baseline estimates as well as the proportion of those maximum allowable emissions which might be allocated to light duty vehicle emissions by the proportionate share of their baseline emissions.

EFFECT OF SPEED ON VEHICLE EMISSIONS. Two major studies have been carried out on the relationship of vehicle speed to emissions for automobiles without pollution-control devices (9 and 10). These studies both found that carbon monoxide and hydrocarbon emissions decrease as average speed increases, but were divided as to the effect of speed on nitrogen oxide emissions. One found no relationship, while the other discovered some evidence that NO_x increased with higher speeds.

A more recent study conducted by the California Air Resources Board (11) is based on only five vehicles. The results of these tests are shown in Figure 28. The tested steady state speeds of these vehicles resulted in the conclusion that hydrocarbon emissions changed very little, dropping off slightly as speed in increased to 30 and 40 miles per hour, and then increasing slightly as speed is further increased to 70 miles per hour. Carbon monoxide averages drop about 40 percent as speed is increased to 30 miles per hour, then increase to over twice the original value (at 20 m.p.h.) as speed is increased to 70 miles per hour. There is considerable variation among the different cars, probably related to differences between the idle and mid-range circuits of the carburetors.

Emissions were also monitored for average speeds on three of the vehicles, represented by a 7-mode procedure which includes idle, acceleration, and deceleration sequences involved in actual driving patterns. Figure 28 also indicates that the general trend of decreasing CO and HC and increasing NO_2 emissions was confirmed for average speeds.

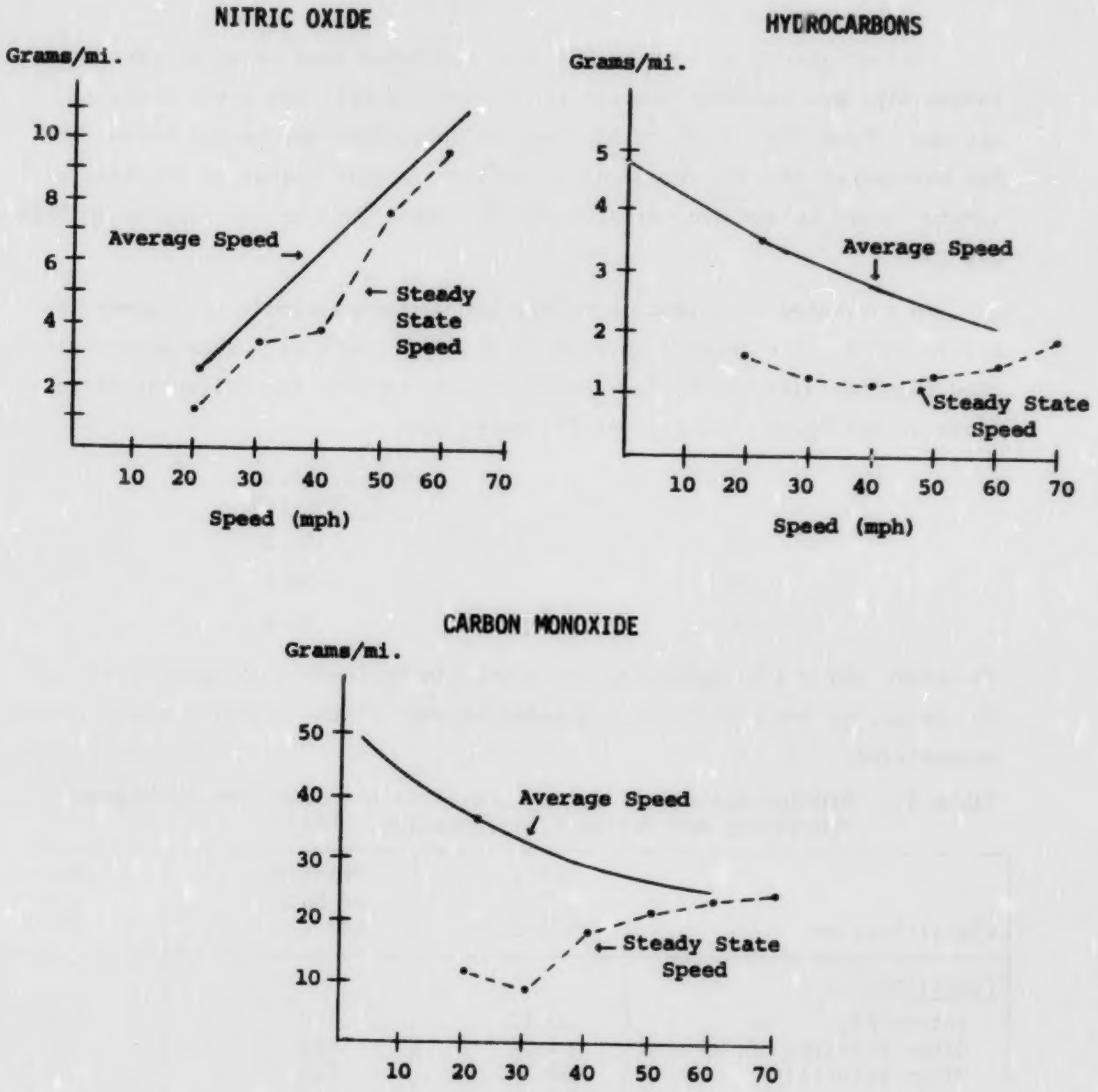


Figure 28. Emissions of NO_x, HC, and CO as a function of speed.

Source: Reference 11. Results based on tests of three cars: (1) 1970 Chev. — 350 in^3; (2) 1964 Chev. — 283 in^3; and (3) 1971 Pont. — 350 in^3.

Further investigations by EPA have indicated that emission-speed relationships are somewhat similar for controlled vehicles with catalytic devices. Hence the relationships may be applicable across the board. EPA has determined factors which can be applied in this manner to emission estimates based on average emission rates. These factors are graphed in Figure 29.

An estimated distribution of average operating speeds by highway facility VMT for Los Angeles in 1972 is shown in Table 41. This distribution, used together with the factors in Figure 29, implies the following corrections to the above calculations for emissions:

	Percent Correction Implied
CO	-36.0
NO_x	+20.2
HC	-28.8

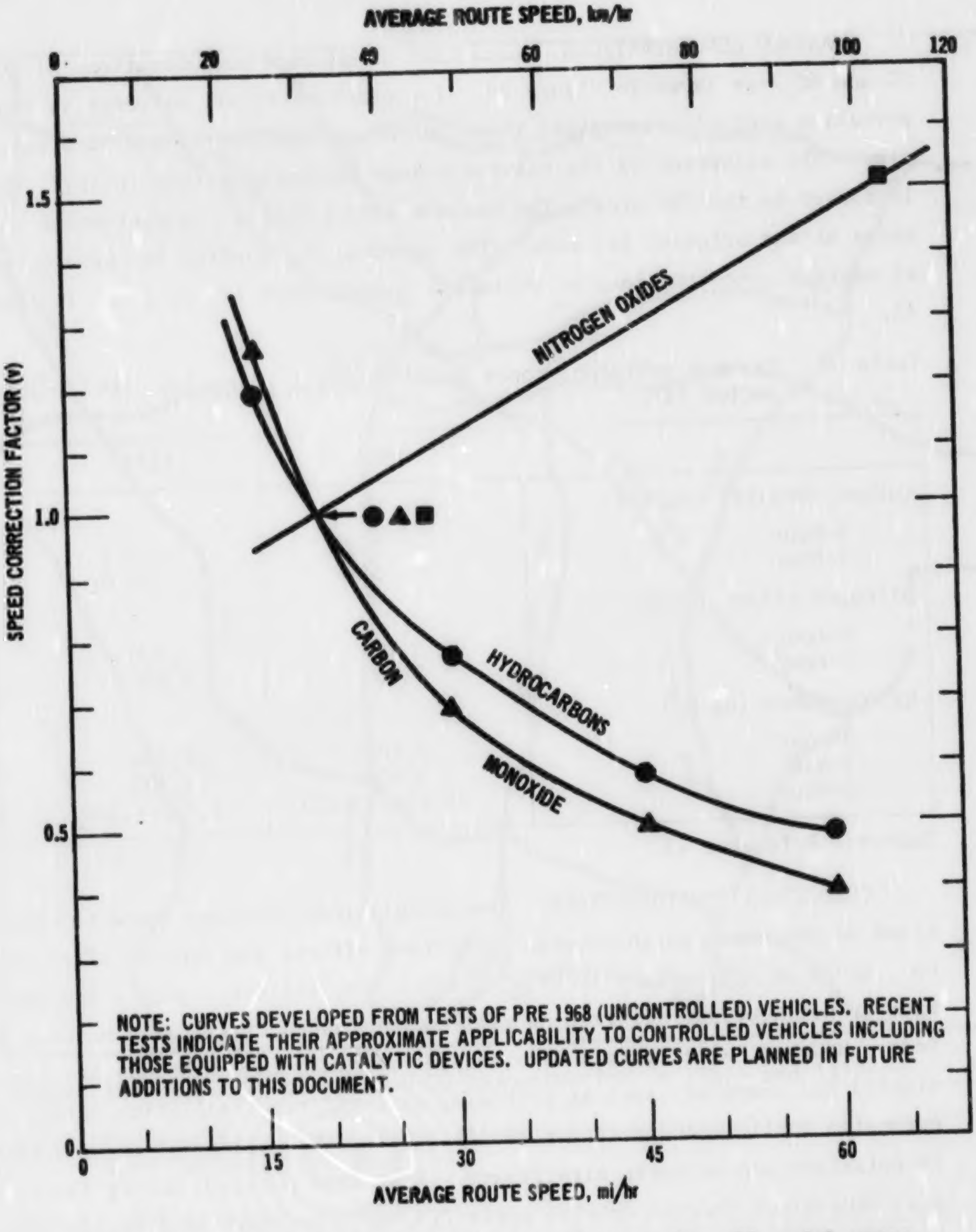
Therefore, CO and HC emissions are likely to be lower than calculated, and NO_x emissions are likely to be greater because of the higher average speeds encountered.

Table 41. Average speeds of highway travel in the SCAG area by highway functional and design classification – 1972.

Classification	Daily VMT (millions)	Fraction of Daily VMT	Average Speed (MPH)
Functional			
Interstate	30.17	.200	55.3
Other Principal Arterials	64.05	.424	36.0
Minor Arterials	33.17	.220	28.5
Collectors	10.06	.067	25.4
Local	13.66	.090	20.5
TOTAL	151.11	1.0	33.2
Design Type (non-local)			
Freeways*	53.1	.351	55.5
Other four-or-more Lanes	41.3	.273	30.4
Less than four Lanes	43.1	.285	27.4
TOTAL	137.5	.910	35.4

*Freeways include Interstate and about 42% of arterial VMT.

Source: Reference 7.



NOTE: CURVES DEVELOPED FROM TESTS OF PRE 1968 (UNCONTROLLED) VEHICLES. RECENT TESTS INDICATE THEIR APPROXIMATE APPLICABILITY TO CONTROLLED VEHICLES INCLUDING THOSE EQUIPPED WITH CATALYTIC DEVICES. UPDATED CURVES ARE PLANNED IN FUTURE ADDITIONS TO THIS DOCUMENT.

Figure 29. Average speed correction factors for all model years.

Source: Reference 12.

MAXIMUM CONCENTRATIONS. Locations of maximum concentrations of CO, HC and NO_x are shown in Figure 30. For practically all alternative transportation control strategies, these concentrations are in the same location. The exception is the maximum 1-hour CO concentration in 1977, which is closer to the CBD area. The maximum 1977 8-hour CO concentration remains at the original location. The expected air quality in these zones of maximum concentration, as estimated in Reference 13, is given in Table 42.

Table 42. Maximum pollutant concentrations for Los Angeles, 1967 and expected 1977.

	1967	1977
Carbon monoxide (mg/m^3)		
8-hour	36.1	7.3
1-hour	51.6	24.0
Nitrogen oxides (μg/m^3)		
8-hour	3,100	1,400
1-hour	3,700	2,400
Hydrocarbons (μg/m^3)		
8-hour	7,600	2,700
1-hour	9,800	4,300
3-hour	15,000-17,000	5,400-7,400

Source: Reference 13.

COLD START CONSIDERATIONS. The calculations relating speed to emissions do not distinguish between cold-start effects and running after warm-up. Given an appropriate average emission rate estimate, such a distinction is not necessary if trip lengths do not change drastically between periods. However, when certain alternatives for reducing emissions are considered and compared, such as providing park-and-ride facilities versus an extensive public transportation feeder system, the cold start contribution to emissions can be quite significant. Test data obtained during the 7.45-mile equivalent federal driving cycle (14) indicate that cold starts contribute the following percentages of the 1971 and 1976 model year emission factors (ratio of differences [14, p. 918] to factors [Table F-1]):

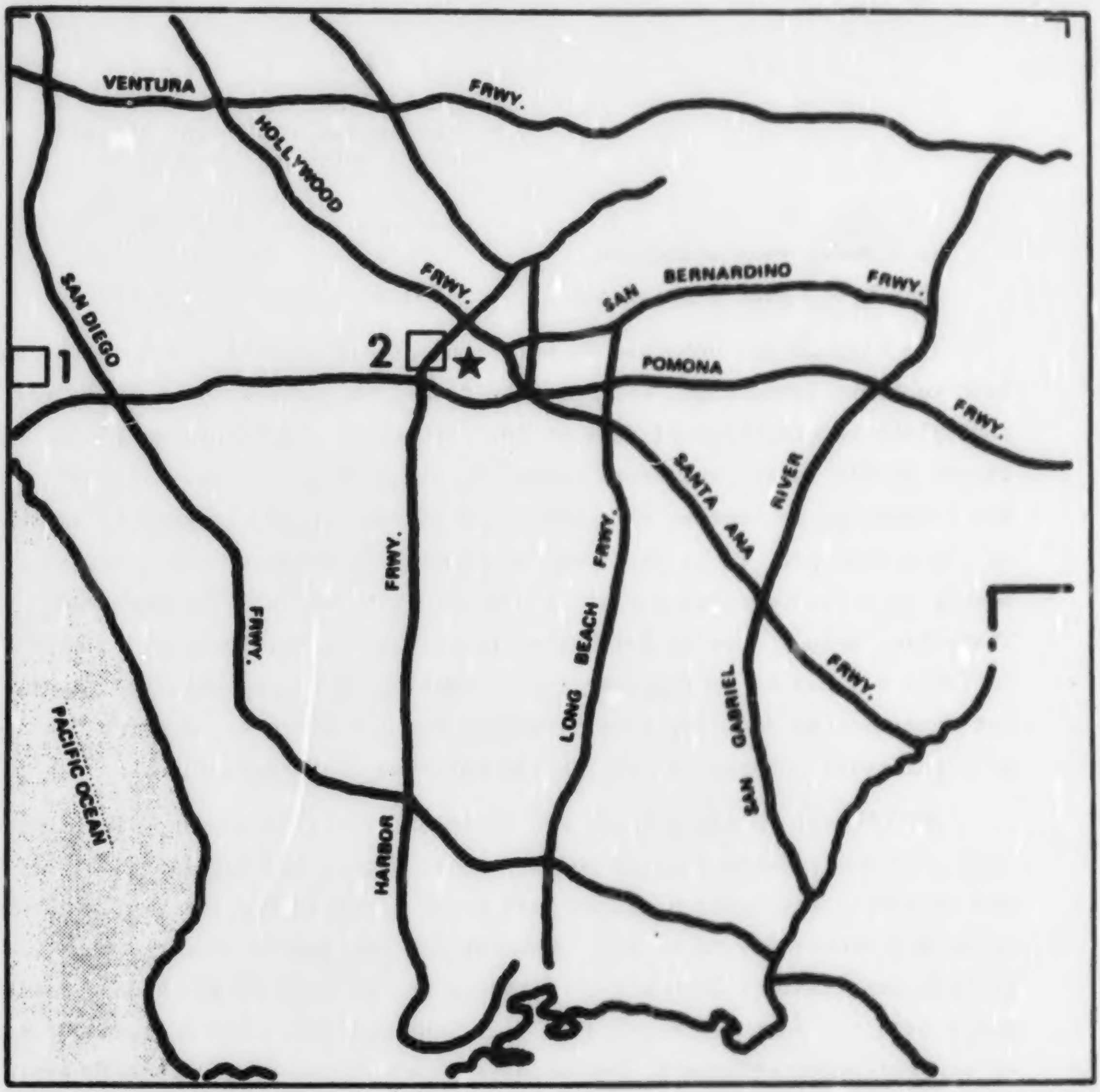


Figure 30. Location of maximum CO concentration in 1967[1] and 1977[2].

Note: Maximum HC and NO_x concentrations are at Location 1 for all cases. Star indicates CBD area.

Source: Reference 13, p. 3-63.

	Cold Start Contribution to Emissions as Percent of Standard Emission Factors		
	CO	NO_x	HC
1971 model year standards	35.5	16.4	23.7
1976 model year standards	170.0	-35.0	87.8

The high CO and unburned HC emission rate in cold starts results from less complete combustion, which can be traced to carburetor choke action, incomplete vaporization of fuel in the carburetor and intake manifolds, and larger quench layers and areas along the sides of piston and cylinder. The technology to improve the combustion of fuel in this regard is currently being studied. It is difficult to predict what improvements future models will incorporate, but it is certain that they will be improved. Therefore, actual data on cold start emissions, as developed by model year in Table 43, may be appropriate for estimating near-term emission rates, but intermediate and long-term estimates are likely to be in error because of significant changes in the vehicle emission characteristics.

IMPROVEMENT IN AIR QUALITY DUE TO EMISSION CONTROLS. As demonstrated above, unquestionably the air pollution problem in Los Angeles is acute, and unusually stringent measures will be required if the air quality standards are eventually to be met. However, on the positive side, it is equally important to document the changes in air quality which have taken place over the past eight years of emission controls. The following summary of air pollutant effects in Los Angeles County is excerpted from an article by Robert L. Chass, "California Looks at Automotive Emissions," Automotive Engineering, October 1973, pp. 52-56.

1. **Ozone**

A. Alerts (instantaneous concentration of 0.5 ppm or higher)

1965 - 6
1966 - 4
1967 - 5
1968 - 4
1969 - 4
1970 - 9
1971 - 1
1972 - 1
All-time high: 15 in 1955

B. Annual Average of Daily Instantaneous Maxima (ppm)

1965 - 0.20
1966 - 0.21
1967 - 0.21
1968 - 0.19
1969 - 0.19
1970 - 0.19
1971 - 0.16
1972 - 0.15
All-time high: 0.26 in 1956

C. Number of Days on Which 0.10 ppm Was Equalled or Exceeded

1965 - 236
1966 - 271
1967 - 259
1968 - 252
1969 - 246
1970 - 241
1971 - 218
1972 - 211
All-time high: 322 in 1958

Table 43. Hot-running and cold-start emissions by model year.

	Hot-running emissions, g/mi			Cold-start emissions, g/start		
Model year	NO_x (as NO_2)	HC	CO	NO_x (as NO_2)	HC	CO
1960 and before	3.50[a]	22.06[a] 2.69 evap. 4.10 blow-by	128.9[a]	5.66	10.73	254.1
1961	3.50[a]	22.06[a] 2.69 evap. 4.10 blow-by	128.9[a]	5.66	10.73	254.1
1962	3.50[a]	22.06[a] 2.69 evap.	128.9[a]	5.66	10.73	254.1
1963	3.50[a]	22.06[a] 2.69 evap.	128.9[a]	5.66	10.73	254.1
1964	3.50[a]	22.06[a] 2.69 evap.	128.9[a]	5.66	10.73	254.1
1965	3.50[a]	22.06[a] 2.69 evap.	128.9[a]	5.66	10.73	254.1
1966	5.64[a]	5.81[a] 2.69 evap.	35.39[a]	5.66	10.73	254.1
1967	5.64[a]	5.81[a] 2.69 evap.	35.39[a]	5.66	10.73	254.1
1968	5.35[b]	3.36[b] 2.69 evap.	37.23[b]	5.66[b]	10.73[b]	254.1[b]
1969	4.40[b]	3.51[b] 2.69 evap.	28.87[b]	6.56[b]	9.54[b]	143.6[b]
1970	5.39[b]	2.65[b] 2.69 evap.	22.67[b]	5.80[b]	10.88[b]	143.3[b]
1971	3.71[b]	2.80[b]	29.66[b]	5.36[b]	6.18[b]	92.53[b]
1972	2.66[a]	2.63[a]	28.70[c]	4.02[d]	4.25[d]	76.74[d]
1973	2.49[c]	2.63[a]	28.70[c]	3.78[d]	4.25[d]	76.74[d]
1974	2.49[c]	2.63[a]	28.70[c]	3.78[d]	4.25[d]	76.74[d]
1975 and after	0.99[b]	0.25[b]	0.90[b]	−1.04[e]	2.68[b]	43.06[b]

[a] Obtained by scaling California standard or estimate of prestandard emission factor to federal test procedure and subtracting cold-start contribution as extrapolated from test data (see text).

[b] Test data (see Table I).

[c] Obtained by subtracting cold-start contribution from federal standard.

[d] Lacking data in the 1972–74 time period, it was assumed that the techniques employed to meet the standards used in obtaining the running emission factors (see *a* or *c* above) would act proportionally in scaling the cold-start emissions down from their 1971 values toward their 1975 values.

[e] Test data. The negative correction is always used in conjunction with the running emission factor, thereby reducing each post-1975 car's net NO_x contribution to the level predicted for a federal cycle with one cold start, followed by hot-running emissions.

Source: Reprinted with permission from Jose R. Martinez, Richard A. Nordsieck, and Alan Q. Eschenroeder, "Morning Vehicle-Start Effects on Photochemical Smog," Environmental Science & Technology 7 (1973):919. Copyright by the American Chemical Society.

D. Number of Days on which Certain Concentrations were Equalled or Exceeded

1. 0.25 ppm
   1965 - 126   1969 - 115
   1966 - 133   1970 - 115
   1967 - 135   1971 - 70
   1968 - 113   1972 - 58
   All-time high: 186 in 1956
2. 0.35 ppm
   1965 - 50   1969 - 49
   1966 - 41   1970 - 41
   1967 - 56   1971 - 19
   1968 - 46   1972 - 13
   All-time high: 89 in 1955
3. 0.4 ppm
   1965 - 26   1969 - 25
   1966 - 22   1970 - 27
   1967 - 24   1971 - 8
   1968 - 23   1972 - 6
   All-time high: 71 in 1955

It is obvious that atmospheric concentrations of ozone are on the decline. The number of alerts has decreased and, for all practical purposes, an alert is a thing of the past. . . .

The annual average of daily instantaneous maxima has been reduced 25%. The number of days that the State air quality standard of 0.1 ppm has been equalled or exceeded has been reduced 11%; the number of days exceeding 0.25 ppm, 54%; 0.35 ppm by 74%; and 0.40 ppm, by 77%. Hence, the intensity of one of the effects of photochemical smog has lessened dramatically. From 1965 to 1968 more alerts occurred in Downtown Los Angeles than in any other part of the County. There has not been an alert in Downtown Los Angeles since 1968.

2. Carbon Monoxide

A. Annual Average of Daily Instantaneous Maxima (ppm)
   1965 - 30   1969 - 19
   1966 - 27   1970 - 20
   1967 - 26   1971 - 19
   1968 - 20   1972 - 19
   All-time high: 30 in 1965

B. Number of Days 10 ppm Averaged for 12 hrs. Was Equalled or Exceeded
   1965 - 365   1969 - 171
   1966 - 365   1970 - 203
   1967 - 363   1971 - 146
   1968 - 185   1972 - 137
   All-time high: 365 in 1965 and 1966

C. Number of Days 40 ppm Hourly Average was Equalled or Exceeded
   1965 - 38   1969 - 15
   1966 - 15   1970 - 11
   1967 - 24   1971 - 4
   1968 - 10   1972 - 4
   All-time high: 38 in 1965

D. Number of Days on which Daily Instantaneous Maxima Equalled or Exceeded

1. 30 ppm
   1965 - 156   1969 - 58
   1966 - 132   1970 - 72
   1967 - 119   1971 - 58
   1968 - 65   1972 - 56
   All-time high: 156 in 1965
2. 40 ppm
   1965 - 64   1969 - 23
   1966 - 45   1970 - 16
   1967 - 42   1971 - 16
   1968 - 16   1972 - 14
   All-time high: 64 in 1965
3. 50 ppm
   1965 - 19   1969 - 6
   1966 - 8   1970 - 2
   1967 - 10   1971 - 3
   1968 - 3   1972 - 3
   All-time high: 19 in 1965

Atmospheric concentrations of carbon monoxide are also decreasing as one would expect. The annual average of daily instantaneous maxima dropped 37%. The number of days experiencing a 12-hr average of 10 ppm or greater decreased 62%; and the number of days having an hourly average of 40 ppm or greater decreased a dramatic 90%. The number of days experiencing an instantaneous value of 30 ppm or greater decreased by 64%; 40 ppm or greater by 78%; and 50 ppm or greater, by 84%.

3. Oxides of Nitrogen

A. Annual Average of Daily Instantaneous Maxima (ppm)
   1965 - 0.55   1969 - 0.61
   1966 - 0.57   1970 - 0.71
   1967 - 0.65   1971 - 0.72
   1968 - 0.64   1972 - 0.70
   All-time high: 0.72 in 1971

B. Number of Days 0.25 ppm NO_2 Equalled or Exceeded
   1965 - 100   1969 - 102
   1966 - 89   1970 - 115
   1967 - 113   1971 - 125
   1968 - 132   1972 - 96
   All-time high: 132 in 1968

The control of exhaust hydrocarbons and carbon monoxide from the 1966 to 1970 model vehicles was accomplished in part at the expense of oxides of nitrogen. The result of attempts to meet the emission standards for the former two contaminants was an increase in emissions of NOx, which averaged more than 50% from such vehicles and ranged as high as 100% in some. Air monitoring data substantiated this. The annual average of daily instantaneous maxima increased in eight years 27%. The number of days which equalled or exceeded 0.25 ppm NO_2 increased from 1965 to 1968 by 32% and has now decreased slightly from 1965.

4. Eye Irritation

The most common effect of photochemical smog is eye irritation. Many studies have been performed in attempts to determine the adverse medical effects on the eye and to establish a reliable method of measuring this subjective manifestation. Medical studies have shown that a person's eyes do indeed become irritated when subjected to smog but when the smog disappears, or when the patient is removed from the affected area, the eye returns to normal. No permanent effect or damage can be attributed to the irritation.

Many different statistical approaches have been used to "measure" eye irritation but the resulting data are still open to question. Eye irritation exists simply because people say so.

A. Number of Days on Which Eye Irritation was Recorded

1965 - 164 1969 - 137
1966 - 176 1970 - 134
1967 - 149 1971 - 125
1968 - 134 1972 - 125
All-time high: 214 in 1962

Even though there has been a 24% reduction in the number of days on which eye irritation is recorded, this effect is still experienced on one-third of the days each year. On the positive side, there has been an improvement, both in intensity of the irritation and in the number of days.

PHILADELPHIA

Introduction

The Metropolitan Philadelphia Interstate Air Quality Control Region (AQCR) comprises 11 counties in a three-state area: five counties in Pennsylvania; five in New Jersey; and one in Delaware. Nine of these counties are included in the Delaware Valley Regional Planning Commission (DVRPC), shown in Figure 31.

About 38 percent of the people within the DVRPC area live in the City and County of Philadelphia and own 27.5 percent of the automobiles in the area. The CBD of Philadelphia has probably experienced the most rapid rate of growth in automobile ownership of any part of the area, with the number of automobiles increasing 88 percent from 1960 to 1970 in the same time that the CBD population increased 13 percent. The population of the nine-county region in 1970 was 5.1 million, with 1.9 million in Philadelphia County and 43,000 in the CBD. Auto ownership was 1.8 million in the region, 494,000 in the county, and 11,000 in the CBD (15). Projections for SMSA populations and population within the 1,689 square mile urbanized portion of the DVRPC area are shown in Table 44, as well as projections of VMT.

Overall, the fastest growing areas have been in the less urbanized Burlington, Bucks, and Chester Counties, indicating that the urbanized area is likely to increase in size significantly as well as in population. However, the problems of air pollution from mobile sources and congestion are still expected to be concentrated within the existing urbanized areas.

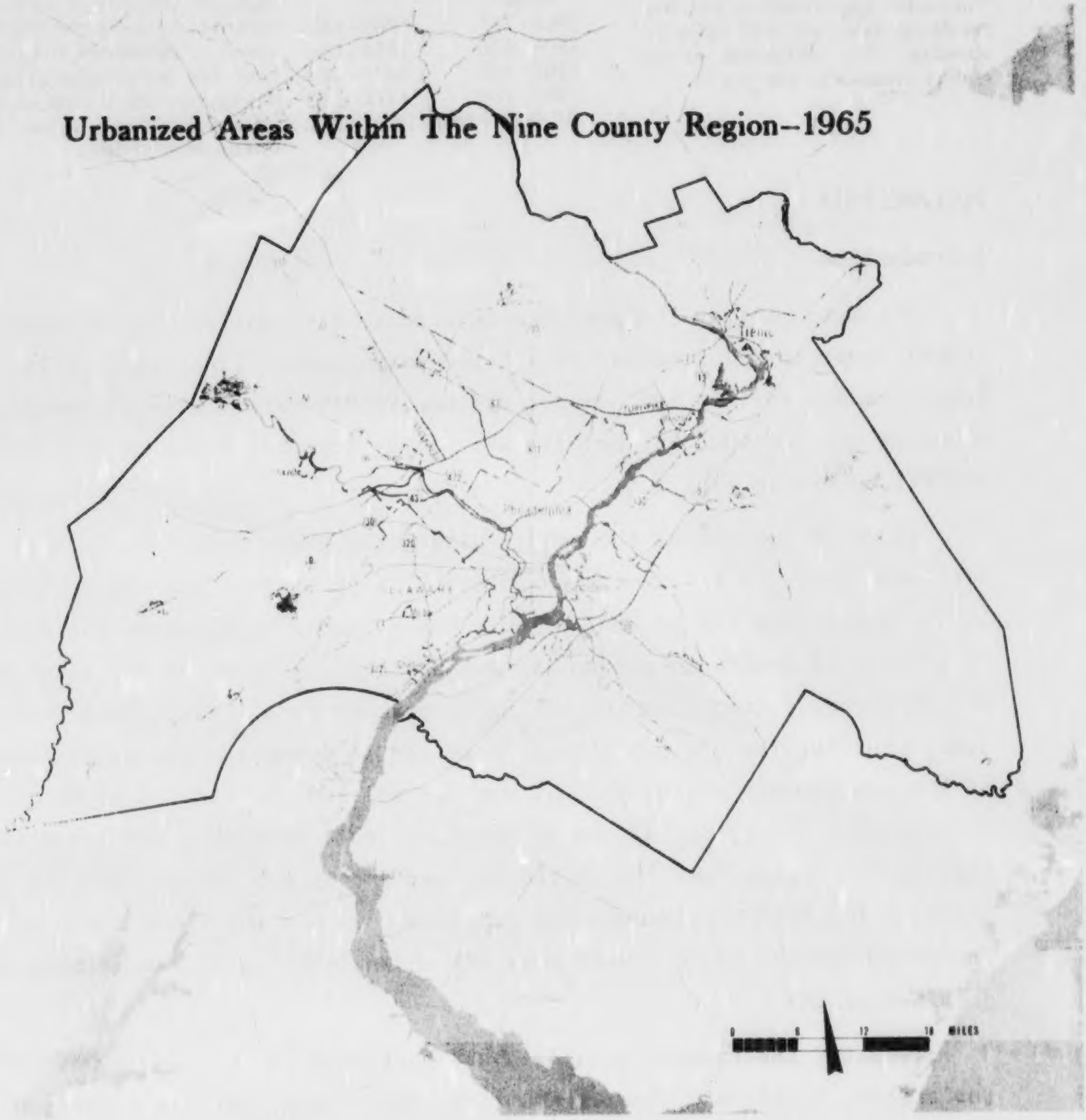


Figure 31. Urbanized areas within the nine-county DVRPC region, 1965.

Source: The Delaware Valley Plan, Delaware Valley Regional Planning Commission, Philadelphia, March 1970.

Table 44. Projections of population and daily vehicle miles traveled for Philadelphia, 1970-2000.

	Population (millions)		Daily VMT in DVRPC Urbanized Area (millions)
	SMSA	DVRPC Urbanized Area	
1970	4.83	--	--
1972	--	4.81	58.93
1975	5.17	--	--
1980	5.52	5.23	75.91
1990	6.23	5.77	97.26
2000	6.94	--	--

Sources: References 16 and 27.

Current Status and Future Trends in Congestion

The major areas of congestion in Philadelphia occur in the central city, with heaviest congestion occurring in the core (Schuykill Expressway), south and west of the city, and on portions of Roosevelt Boulevard, Penrose Avenue, City Lane Avenue, and Walnut-Chestnut Street, especially in areas near the Schuykill Expressway. These and other areas have been selected for TOPICS improvements which are in progress. The contribution of light and heavy duty vehicles to VMT is shown in Tables 45 and 46.

Table 45. Estimated daily VMT for Philadelphia by vehicle type, 1970 and 1977.

	CBD (10^6 VMT/day)			Citywide (10^6 VMT/day)		
	1970	1977	%	1970	1977	%
Automobiles	544.	592.	80.0	9,010	9,945	85.0
Taxis	54.4	59.2	8.0	318	351	3.0
Light trucks	27.2	29.6	4.0	636	702	6.0
TOTAL Light Vehicles	625.6	680.8	92.0	9,964	10,998	94.0
Medium and Heavy Trucks	13.6	14.8	2.0	477	526.5	4.5
Buses	40.8	44.4	6.0	159	175.5	1.5
TOTAL Heavy Vehicles	54.4	59.2	8.0	636	702.	6.0
TOTAL	680.0	740.0	100.0	10,600	11,700.	100.0

Source: Reference 18.

Table 46. Daily VMT for DVRPC area by vehicle type, 1960.

	Percent of VMT
Automobiles	86.2
Taxis	0.9
Light trucks	6.3
Heavy trucks	6.6
TOTAL	100.0

Source: Reference 18.

The projected average speeds for different types of highway facilities given in Table E-3 (Appendix E) show an increase over time for each facility. The increase in average speed implies that in spite of greater utilization of the facilities, TOPICS traffic flow improvements which are planned should, in fact, lead to a decrease in congested conditions.

To obtain a rule-of-thumb indication of the roadway investment costs which are likely to be incurred to accommodate the travel projections of Table E-3, the annual incremental investment cost per annual incremental vehicle-mile estimator developed in Section 2 (p. 32) can be applied. From 1972-1990, an increase of 38.33 million VM per day is projected, or 13,990 million vehicle-miles for the 18-year period—an average annual increase of about 777 million vehicle-miles. Assuming an average annual incremental cost per vehicle-mile of $0.018, an annual incremental cost of $14 million is implied. The cumulative incremental cost for increases in vehicle-miles over the next 20 years then becomes about $2.7 billion.

If this calculation is performed using the estimated incremental cost for new urban roadway construction and rights-of-way of $0.0087 derived in Section 2, the average annual incremental cost becomes $6.76 million (777 million × 0.0087). The result is a 20-year cumulative cost of $1.3 billion, which represents the estimated sum required solely for new roadway construction and rights-of-way in Philadelphia over the next 20 years to accommodate anticipated increases in travel of some 14 billion vehicle-miles. This value of $1.3 billion, then, provides a basis for comparing the projected investment costs of alternative strategies designed to reduce congestion, air pollution and energy use in the Philadelphia area in conjunction with their tradeoffs in terms of concomitant social benefits and costs.

Air Pollution

A 1967 air pollution study for Philadelphia indicated that mobile sources are responsible for 70 percent of the CO emissions, 47 percent of the HC emissions, and 27 percent of the NO_x emissions (19). If projections for the AQCR are considered, mobile sources are not expected to remain significant contributors to HC and NO_x emissions, once the full impact of the Federal Motor Vehicle Emission Control Program begins to be felt about 1977 to 1980. Table 22, Section 2 (p. 51) shows such projections for both mobile and stationary emissions as they had been estimated in 1971 and a comparison with the goals to be met. For mobile emissions, only CO remains as a significant problem up to 1985, according to these projections.

However, emissions estimates made in 1971 have had to undergo significant updating since then as changes in requirements have occurred and new data obtained. Table 47 shows a recent estimate and projection of emissions by mobile sources made for the urbanized portion of the nine-county DVRPC area. These estimates imply an underestimation of the absolute value of current emissions in Table 22. Since about the same factors were used for determining the maximum emissions for the National Ambient Air Quality Control Standards (NAAQS) to be met, these maximum emissions are likely to be underestimated as well. Therefore, the conclusion reached above is likely to remain valid (that mobile source emissions of HC and NO_x will be reduced to acceptable levels by 1980).

Projections for air quality within the City of Philadelphia present an even more optimistic picture. The General Motors Research Laboratories used a simple proportional emission rollback to calculate and project the pollutant concentrations shown in Figure 32 under interim standards for 1975 and two standards for 1976. According to these projections, NO_x is not really a problem, and oxidants related to HC as well as CO levels should be well within the air quality standards by 1980.

Table 47. **Mobile emission projections for the urbanized portions of the DVRPC area.**

Emission Type	Quality of Emissions (10^3 tons/year)		
	1972	1980	1990
CO	1723.9	405.5	324.8
HC	147.2	59.1	35.1
NO_x	275.8	131.7	39.4

Based on Reference 16.

Note: Average emission factors used in the calculations are given in Appendix F, Table F-9.

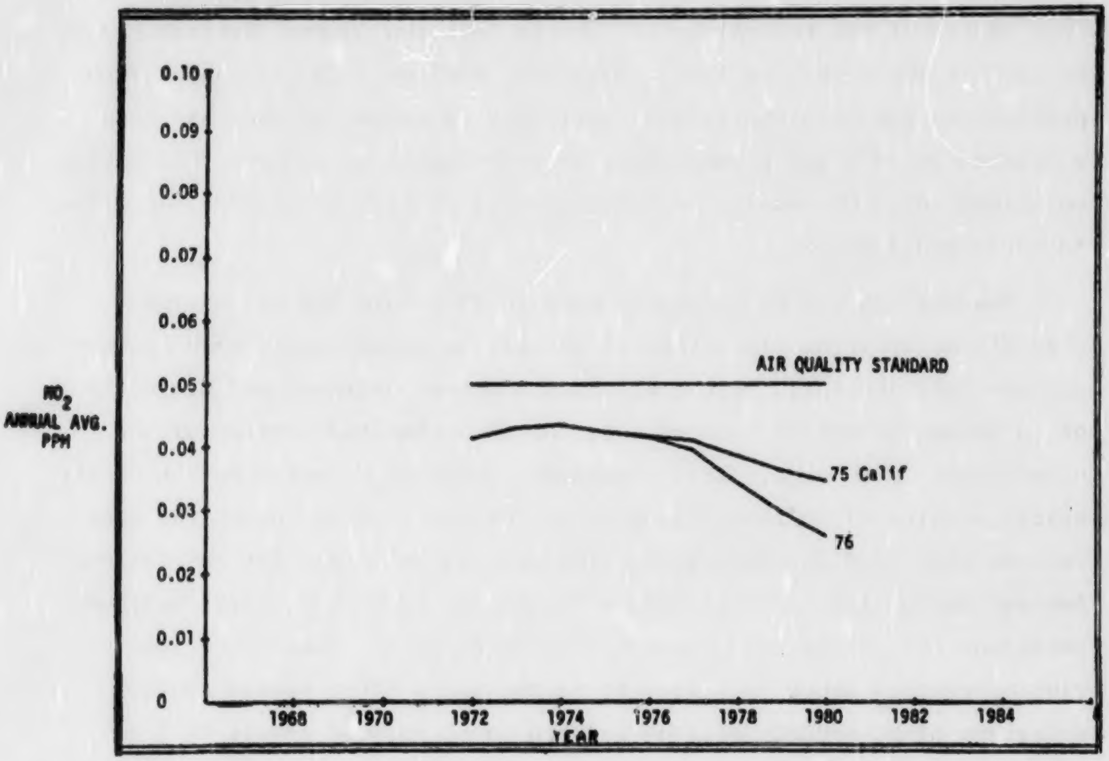


Figure 32. See page facing.

NOTE: Projections were made under the following interim average automobile emission standards for 1975 and later models:

		HC (gpm)	CO (gpm)	NO_x (gpm)
75 California	1975	1.5	15	3.1
	1976 and later	0.9	9	2
76	1975	1.5	15	3.1
	1976 and later	0.41	3.4	0.4

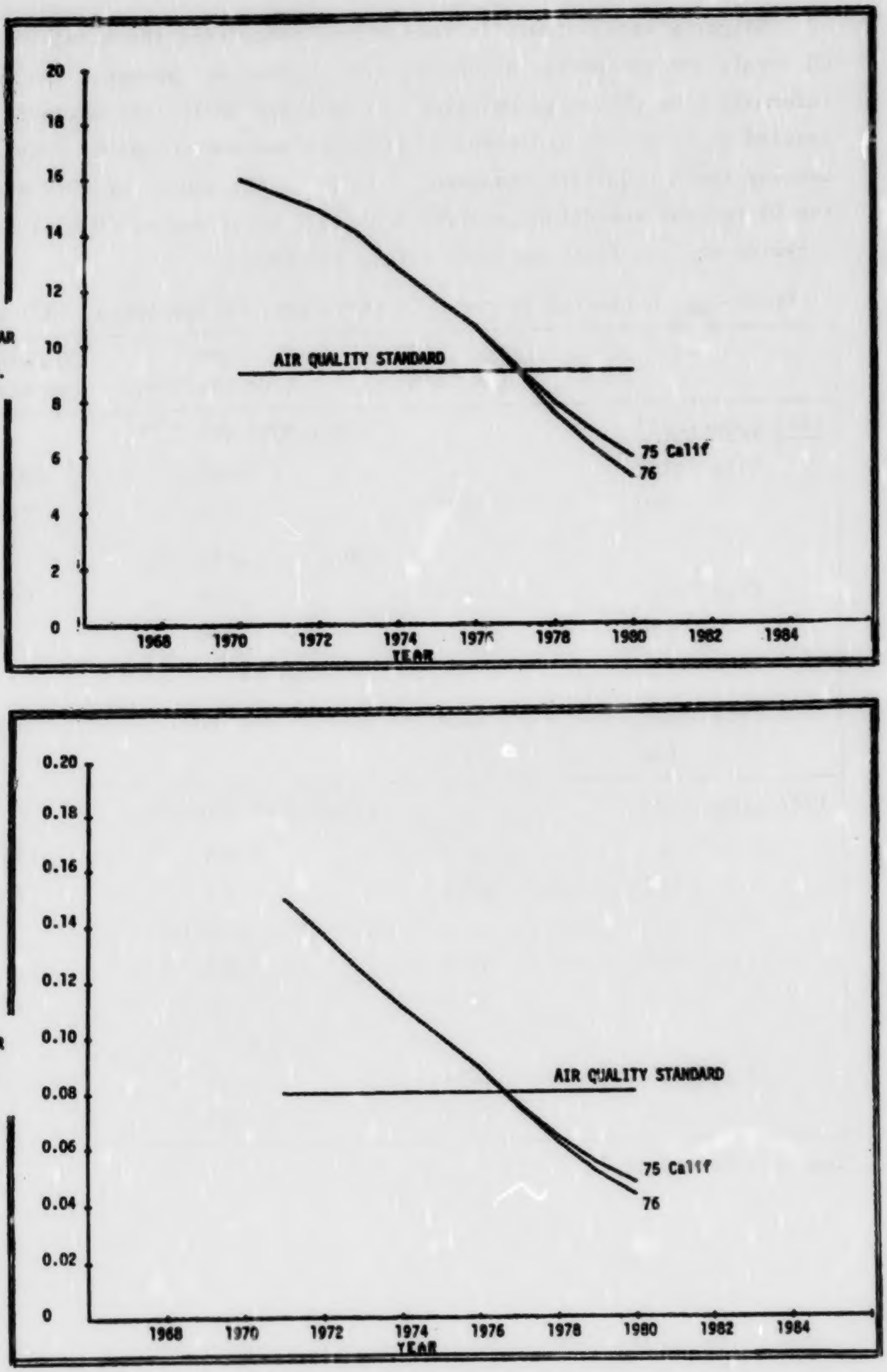


Figure 32. Projections for air pollutant concentrations in Philadelphia.

Source: Reference 17, Part 3, pp. 1501, 1517, 1531.

Slightly less optimistic indications concerning the attainment of CO levels are presented in Reference 18. Table 48a presents the background information on estimated emissions in 1971 and 1977. The estimates are totaled in Table 48b and compared with the maximum emissions required for meeting the Air Quality Standards. As Table 48b shows, by 1977 most of the 54 percent reduction required from 1971 emissions of CO will be achieved citywide and, in fact, exceeded within the CBD.

Table 48a. Estimated year-end CO emissions, Philadelphia, 1971 and 1977.

	Emission Factor (gm CO/mi.)	VMT (10^3 mi./day)	CO Emissions (tons/year)
1971 (year-end)		LIGHT DUTY VEHICLES	
City Total	65.7	10122	267340
CBD	85.7	636	21910
		HEAVY DUTY VEHICLES	
City Total	129.6	569	29640
CBD	169.2	48	3270
		DIESEL	
City Total	20.4	77	630
CBD	20.4	7	60
1977 (year-end)		LIGHT DUTY VEHICLES	
City Total	26.8	11094	119570
CBD	27.3	697	7650
		HEAVY DUTY VEHICLES	
City Total	94.7	618	23530
CBD	96.1	31	1200
		DIESEL	
City Total	20.4	84	690
CBD	20.4	28	230

Source: Reference 18.

Table 48b. CO emissions reduction requirements, Philadelphia City & CBD, 1971 and 1977.

	October, 1971	July, 1977	
	Estimated Actual	Estimated Actual Without Transportation Controls(1)	Estimated Actual Required
Citywide			
Ambient air quality 22.5 mg/m^3 CO, 8-hour average	22.5	-	10
Mobile source emission ton/yr. CO	302000	159000	133000
% Reduction	-	47	56
CBD			
Mobile source emission, ton/yr. CO	25500	10000	11200
% Reduction	-	61	56

(1) Reductions reflect new car emission controls scheduled to be in service and major highway changes programmed for completion as of February 1973.

Source: Reference 18, p. 29.

SEATTLE AND THE PUGET SOUND REGION

Introduction

For the purposes of regional transportation planning as carried out by the Puget Sound Governmental Conference (PSGC), the Puget Sound Region includes four counties. These counties are King County, Snohomish County, Pierce County, and Kitsap County. King and Snohomish Counties have been designated as the Seattle-Everett Standard Metropolitan Statistical Area (SMSA) and Pierce County as the Tacoma SMSA, after the largest cities in the area. The Puget Sound Region is shown in Figure 33.

In 1970 the total population of the 6,295-square-mile region was over 1.9 million. About 60 percent of the population lives in the 2,126 square miles of King County. The distribution of population among the cities and counties of the region is shown in Table 49. King County is the center of growth and activity for the region, and selected trends and projections for the county are shown in Table 50.

Table 49. Population in the Puget Sound Region, counties and cities over 50,000 in 1970.

SEATTLE-EVERETT SMSA			1,424,605
King County		1,159,369	
Bellevue	61,485		
Seattle	530,831		
Snohomish County		265,236	
Everett	53,622		
TACOMA SMSA			412,344
Pierce County		412,344	
Tacoma	154,689		
OUTSIDE SMSAS			101,732
Kitsap County		101,732	
TOTAL — 4 Counties			1,938,681

Source: Reference 21.

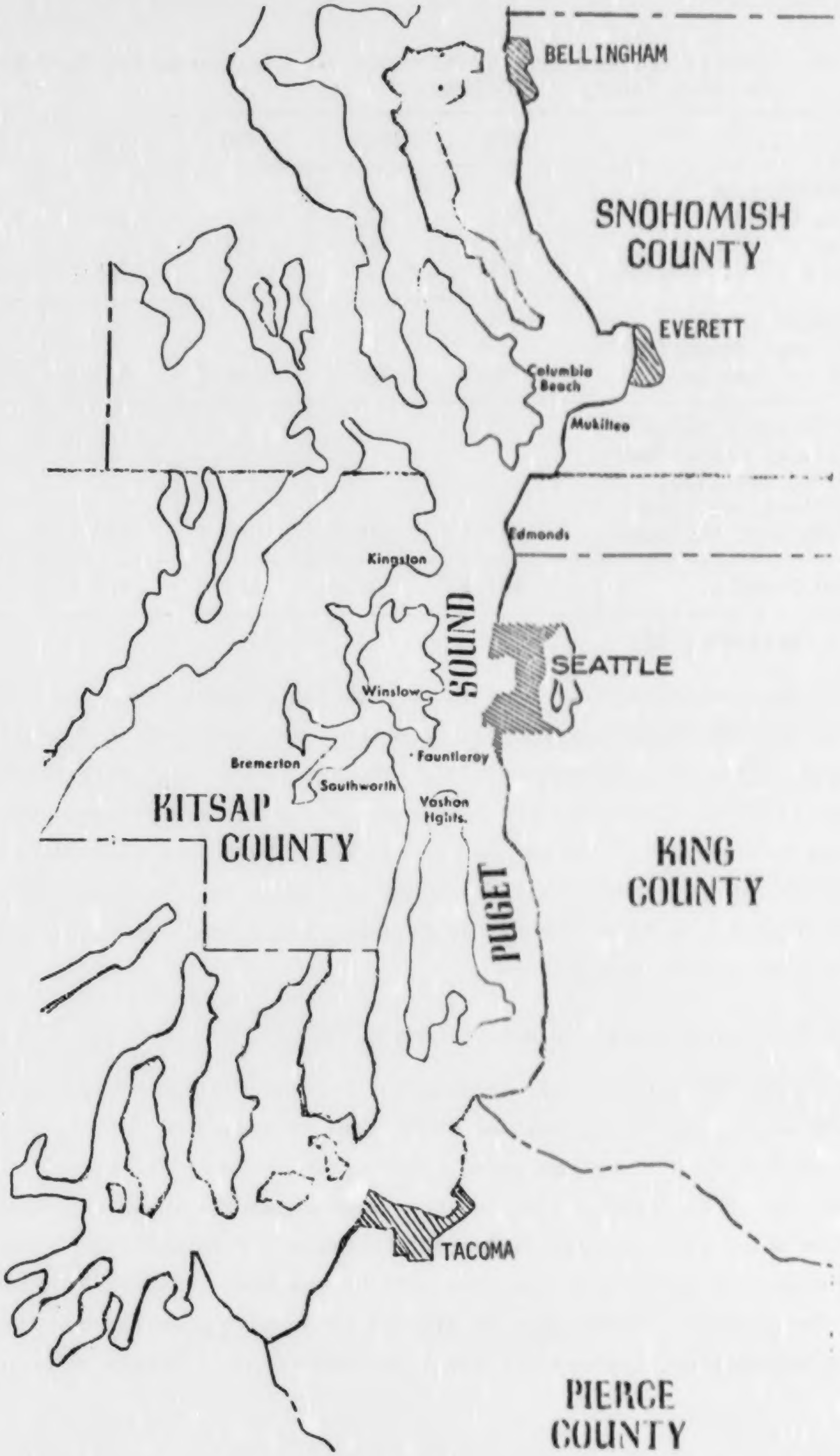


Figure 33. Seattle and the Puget Sound Region.

Source: Reference 20, Vol. 3, p. 201.

Table 50. Population, employment and motor vehicle trends and forecasts for King County, 1950-1990.

	1950	1960	1970	1980	1990
POPULATION (000)					
King County	733	935	1,157	1,260	1,476
City of Seattle	468	557	531	540	540
State of Washington	2,379	2,853	3,409	3,765	4,335
EMPLOYMENT (000) Includes domestics and self-employed	295.7	387.4	495.6	546.8	641.3
MOTOR VEHICLES (000) Includes trucks and public vehicles; trailers and motorcycles not included	263.6	439.5	625.7	730.8	885.6
HOUSEHOLD UNITS	252.4	334.0	423.8	472.5	560.9

Source: Reference 22.

The data presented here is derived from two different sources. The first is the EPA study Transportation Controls to Reduce Motor Vehicle Emissions in Seattle, Washington (23). The second is data currently being analyzed by PSGC. The EPA study data and conclusions are determined for the urbanized areas of Seattle and Tacoma, which have been modeled by a grid of 50 one-square mile units as shown in Figure 24. The PSGC data was derived from the Mainland and Kitsap Transportation Study areas which cover 1,373.1 miles around Seattle.

Current Status and Future Trends in Congestion

The available statistical information relevant to congestion for the Mainland and Kitsap Transportation Study area is presented in Tables 51 and 52. According to the average speed projections of Table 51, if the currently adopted plan is executed, speeds on the major *arterials* in 1990 in the area will show an overall average (weighted) increase. This indicates, broadly, that the overall level of congestion will be somewhat less in 1990 than in 1970. Conversely, if the plan considered to be most probable for execution is implemented, the overall level of congestion is likely to be about

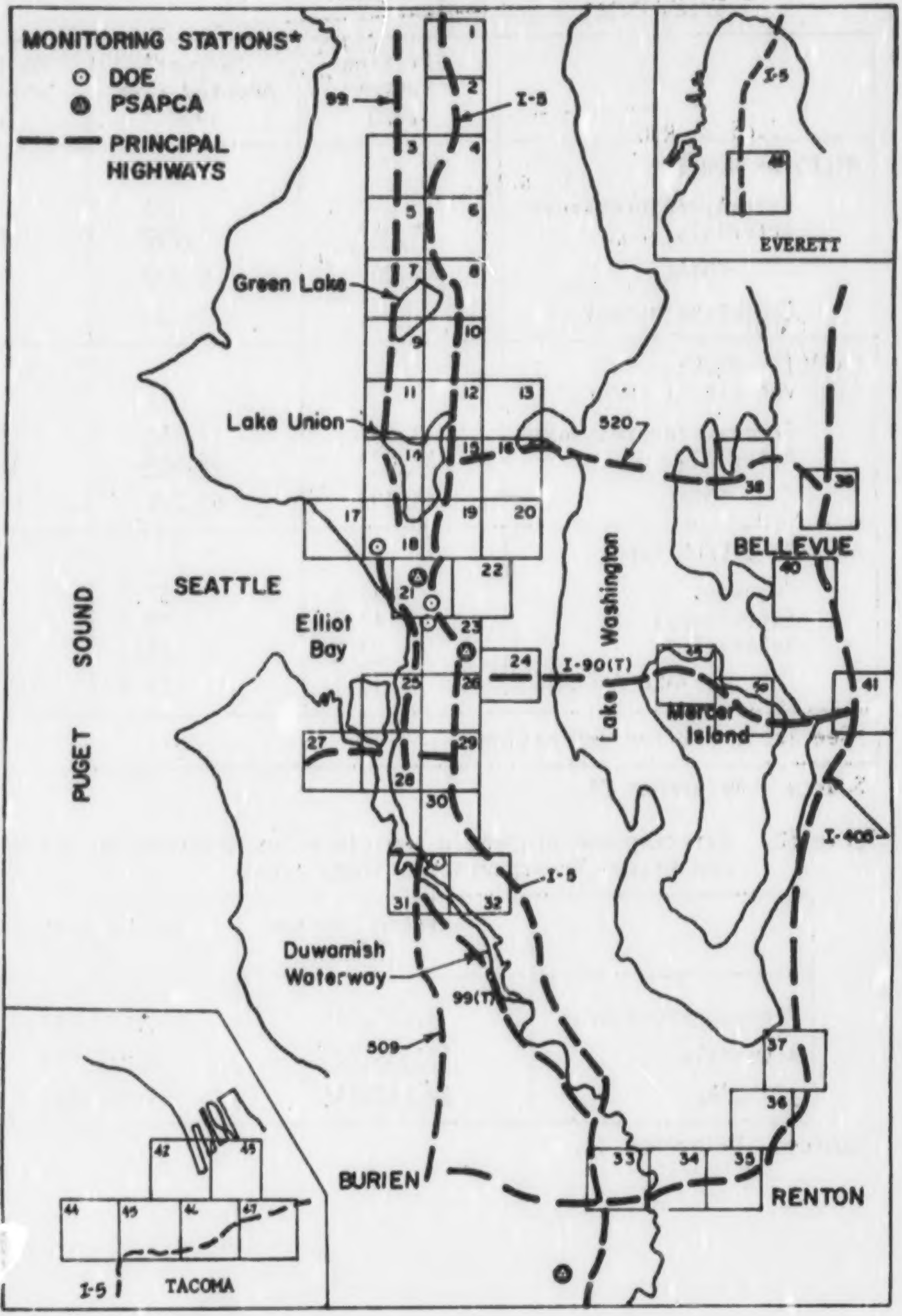


Figure 34. Locations of one-mile-square grids – Seattle area.

*DOE: Department of Ecology; PSAPCA: Puget Sound Air Pollution Control Area.

Note: The CBD is located at approximately Zone 21.

Source: Reference 23, p. II-42.

Table 51. Existing and projected highway route miles, capacity miles and average speeds for Mainland and Kitsap Transportation Study area, Puget Sound Region.

	Existing System 1970	Currently Adopted Plan 1990	Most Probable Plan 1990
MILES OF ROUTE			
Freeways/expressways	217	473	361
Arterials	1,852	1,762	1,855
TOTAL	2,069	2,232	2,216
Exclusive busway	--	20	124
CAPACITY MILES (10^3 vehicle miles/hr)*			
Freeways/expressways	13,664	27,153	20,182
Arterials	32,829	35,569	37,960
TOTAL	46,493	62,722	58,142
AVERAGE SPEEDS (mph)			
Freeways	53.9	51.0	38.8
Expressways	47.7	49.9	45.4
Arterials	23.2	25.1	24.3
OVERALL AVERAGE	30.1	38.6	30.5

*See Table E-2 for definition.

Source: Reference 24.

Table 52. Existing and projected vehicle-miles traveled in the Mainland and Kitsap Transportation Study areas.

	Existing system 1970	Adopted plan for 1990
Freeway/expressway	8,908,314	21,849,028
Arterials	13,335,231	9,918,613
TOTAL	22,243,545	31,767,641

Source: Reference 24.

the same in 1990 as in 1970. Notable under either assumption is the anticipated decrease in average *freeway* speed—deteriorating to an average speed of less than 40 m.p.h. in 1990 should the less extensive, but more probable, plan be implemented.

The only available vehicle-mile projections are shown in Table 52. Unfortunately, these projections are made only for the major arterials, freeways, and expressways. Since the incremental cost per vehicle-mile estimators developed in Section 2 of this report were based on past investments for all functional classifications, they cannot be applied here to estimate probable incremental costs which would be incurred to accommodate the projected increases in vehicle-miles of travel.

Tables 53-55 show the available data for the urban areas of Seattle and Tacoma. According to Table 54, neither the temporal distribution nor the distribution of vehicle-miles by vehicle type is anticipated to change in the 1971-1977 period.

The only estimates of the status and future trends in congestion available for the Seattle-Tacoma central city area were located in the above-referenced study for EPA (23) and result from a system simulation study performed in 1971. The output of this study indicates that only about one percent of the daily vehicle-miles traveled in the central city region were traveled under congested conditions in 1971. The 1977 systems simulation results show a doubling of this figure to about 2.8 percent of the daily vehicle-miles traveled in 1977. If all of this congested travel were assumed to occur in the highest peak hour, some 9 percent of the total daily traffic would be involved, and in 1971 about 11 percent of this peak-hour travel would have been subjected to congestion (1 ÷ 9). Using the same assumptions for the 1971 projection of 2.8 percent of total traffic being congested implies that 31 percent (2.8 ÷ 9) of the peak-hour traffic is likely to be subjected to congested conditions—well over the national average documented in Section 2.

Table 53. Percent of daily traffic for various peaking considerations in the urban areas of Seattle and Tacoma.

Peaking Period	Time	Percent of Daily Traffic
Highest peak hour	4 - 5 p.m.	9.0
Second highest peak hour	5 - 6 p.m.	8.4
Third highest peak hour	7 - 8 p.m.	7.6
Morning 3 hour peak period		
Home-work peak	6 - 9 a.m.	17.7
Highest morning peak period	8 - 10 a.m.	18.3
Evening 3 hour peak period	3 - 6 p.m.	24.5
Highest 8 hours	10 a.m. - 6 p.m.	51.8

Source: Reference 23.

Table 54. Vehicle-miles traveled in the urban areas of Seattle and Tacoma, 1971, 1977.

	Peak Hour	12-Hour	24-Hour	Distribution
1971				
Light duty vehicles	467,510	3,855,696	5,189,360	.888
Heavy duty vehicles	47,911	395,139	531,821	.091
Diesel	11,098	91,207	122,757	.021
TOTAL	526,479	4,342,042	5,843,938	1.0
1977				
Light duty vehicles	517,643	4,269,163	5,745,842	.888
Heavy duty vehicles	53,044	437,478	588,793	.091
Diesel	12,241	100,962	135,885	.021
TOTAL	582,928	4,807,603	6,470,520	1.0

Source: Reference 23.

Table 55. Distribution of 1977 8-hour VMT by average speed in the Seattle central city area.

Average speed (mph)	Percent VMT
50	35.4
25	0.6
20	43.0
18	10.2
15	10.4
12	0.4
	100.0

Source: Based on Reference 23.

Air Pollution

An inventory of 1970 emissions in King County, shown in Table 56, indicates that motor vehicles accounted for 713,559 tons, or 96 percent of the total CO emissions, and 118,283 tons, or 76.7 percent of the total HC emissions for the year. The emissions by motor vehicles in King County account for about 65.1 percent of the CO emissions by motor vehicles in the whole Puget Sound Intrastate Air Quality Control Region (AQCR), and for about 63.8 percent of the HC emissions by motor vehicles in the AQCR. The CO and HC emission inventories for the AQCR are given in Tables 57 and 58. Projections for 1975 inventories are also included in the last two tables. Nitrogen oxides are not a problem in Seattle.

Monitoring of air quality for CO and oxidants related to HC in the Seattle region is carried out jointly by the Washington State Department of Ecology (DOE) and the Puget Sound Air Pollution Control Agency (PSAPCA). During the period of January 1970 to May 1972, concentration measurements were made at seven locations. The highest and second highest concentrations which are used for air quality control purposes are given in Tables 59 and 60. The tables also compare the measurements with national standards and indicate the percent reduction required at each site.

Reference 23 presents a special distribution of emissions over the one mile square grids overlaying the heavily urbanized areas. These dis-

Table 56. Emission estimates for King County in 1970 by source.

SOURCE CATEGORY	CO EMISSIONS (TONS/YEAR)	HC EMISSIONS (TONS/YEAR)
Fuel combustion	4,469	2,126
Process losses	598*	7,959
Solid waste disposal	9,418*	2,100
Transportation		
Motor vehicles	713,559 (96%)	118,283 (76.7%)
Aircraft	5,077*	3,066
Other	6,977	20,146
Miscellaneous area	2,858*	572
Subtotal (Non-vehicular)	29,397 (4%)	35,969 (23.3%)
TOTAL	742,956	154,252

*From sources not likely to significantly affect the CBD.

Source: Reference 23.

Table 57. CO emission estimates for Puget Sound Intrastate AQCR.

SOURCE CATEGORY	EMISSIONS (TONS/YEAR) 1970	EMISSIONS (TONS/YEAR) 1975
Process losses	9,627	7,197
Fuel combustion	8,363	8,363
Transportation*		
Motor vehicles	1,095,438 (94%)	809,438 (93.4%)
Other	18,505	18,505
Solid waste disposal	23,782	14,052
Miscellaneous area sources	8,675	8,175
Subtotal (Non-vehicular)	68,952	56,292
TOTAL	1,164,390	865,730

*1970 values have been distributed in accord with breakdown given in King County 1970 estimates (Appendix C, Implementation Plan). "Other" transportation emissions are left unchanged for 1975.

Source: Reference 23.

Table 58. Hydrocarbon emission estimates for Puget Sound Intrastate AQCR.

SOURCE CATEGORY	EMISSIONS (TONS/YEAR)	
	1970	1975
Process losses	13,520	13,520
Fuel combustion	4,623	4,623
Transportation*		
Motor vehicles	185,791 (75.2%)	124,391 (67.8%)
Other	36,447	36,447
Solid waste disposal	5,100	3,075
Miscellaneous area sources	1,736	1,636
Subtotal (Non-vehicular)	61,426	59,301
TOTAL	247,217	183,692

*1970 values have been distributed in accord with breakdown given in King County 1970 estimates (Appendix C, Implementation Plan). "Other" transportation emissions are left unchanged for 1975.

Source: Reference 23.

tributions for 1971 and 1977 emissions are shown in Figures 35 and 36. The heaviest emission densities are near or in the CBD area as shown by the shaded blocks. Since this was the case, a closer look was taken at emissions in the CBD area for projections. It is sufficient for considerations of CO emission to take the single grid square at Zone 21. However, HC emissions take some time to form oxidants detrimental to public health. Since the emissions drift with the air currents, consideration of a single grid is not justified, so the study looked at a 23-square mile area around the CBD for HC emissions.

The 1971 inventory and observed air quality measurements are given in Table 61. A comparison with the national standards indicates that a reduction of 56 percent in CO vehicular emissions and 36 percent in HC vehicular emissions is required in order to meet the standards. The Federal Motor Vehicle Control Program, as it was defined in December 1972,

Table 59. Summary data for estimating required reductions in CO emissions.

			Concentration (ppm)			Reduction Required Percent	
Station	Sampling Period	Averaging Time	Highest	2nd Highest	National Standard**	Based on Highest	Based on 2nd Highest
I-5 & Dearborn*	July 1970-Oct. 1970	1-hour	35	28	35	0	0
		8-hour	21	20	9	57	55
Municipal Bldg.	July 1971-July 1972	1-hour	38	31	35	8	0
		8-hour	21	20	9	57	55

*Used in Implementation Plan.

**Not to be exceeded more than once per year.

Source: Reference 23.

Table 60. Summary data for estimating required reductions in hydrocarbons emissions.

			Oxidant Concentration (ppm)			Reductions in Hydrocarbons Req'd. (%)	
Station	Sampling Period	Averaging Time	Highest	2nd Highest	National Standard**	Based on Highest	Based on 2nd Highest
I-5 & Dearborn*	July 1970-Oct. 1970	1-hour	0.16	0.15	0.08	53	48
Food Circus	Jan. 1970-May 1972	1-hour	0.11	0.10	0.08	26	18
Duwamish	June 1972-July 1972	1-hour	0.13	0.10	0.08	38	18

*Used in Implementation Plan. Only values measured between 0900 and 1600 PST were considered.

**Not to be exceeded more than once per year.

Source: Reference 23.

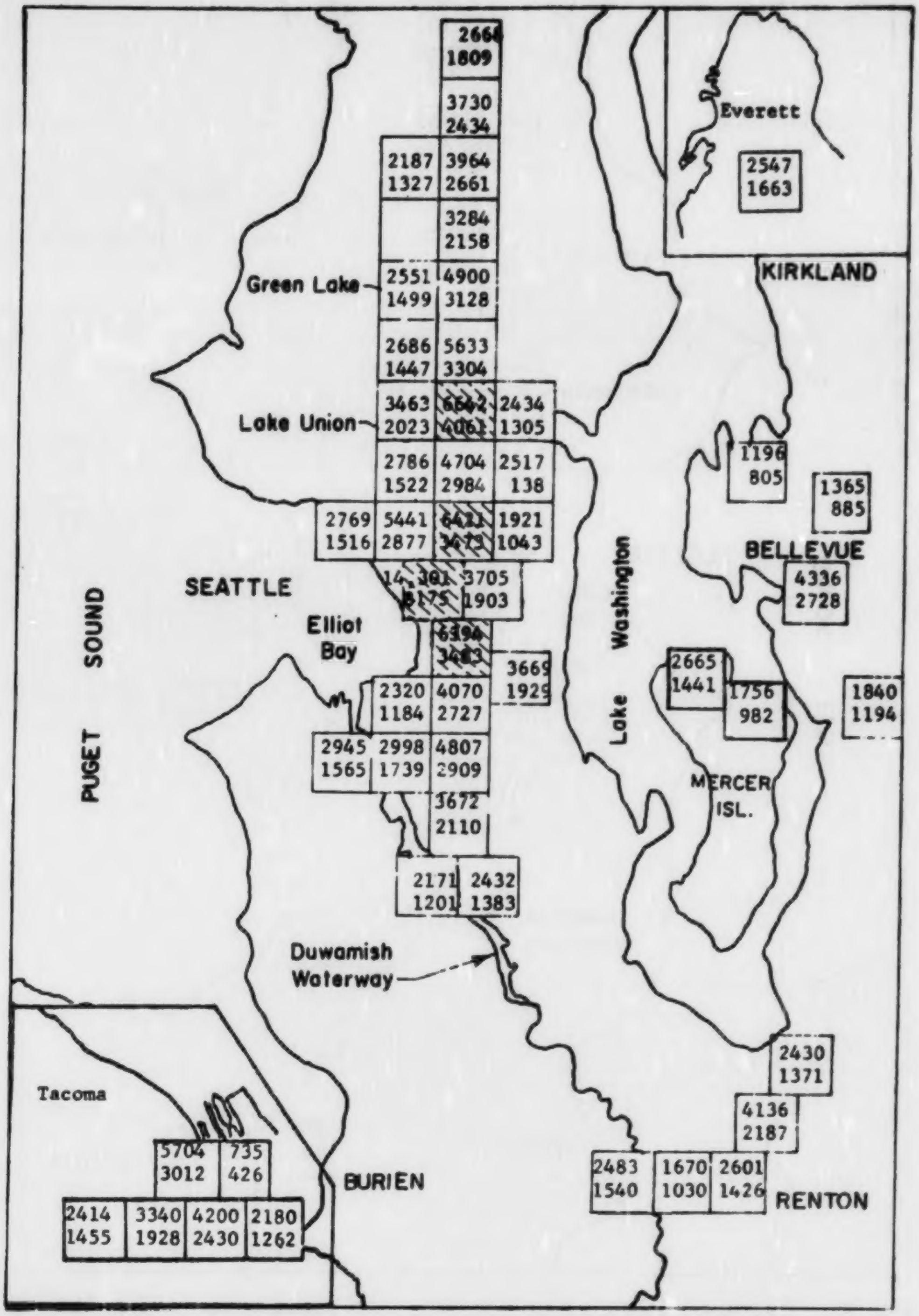


Figure 35. Maximum 8-hour CO emission densities in Seattle (Kgm/sq. mi.).

Note: Upper values are for 1971, lower values are 1977 emissions based on Federal Motor Vehicle Control Program current as of December 1972.

Source: Reference 23, p. II-58.

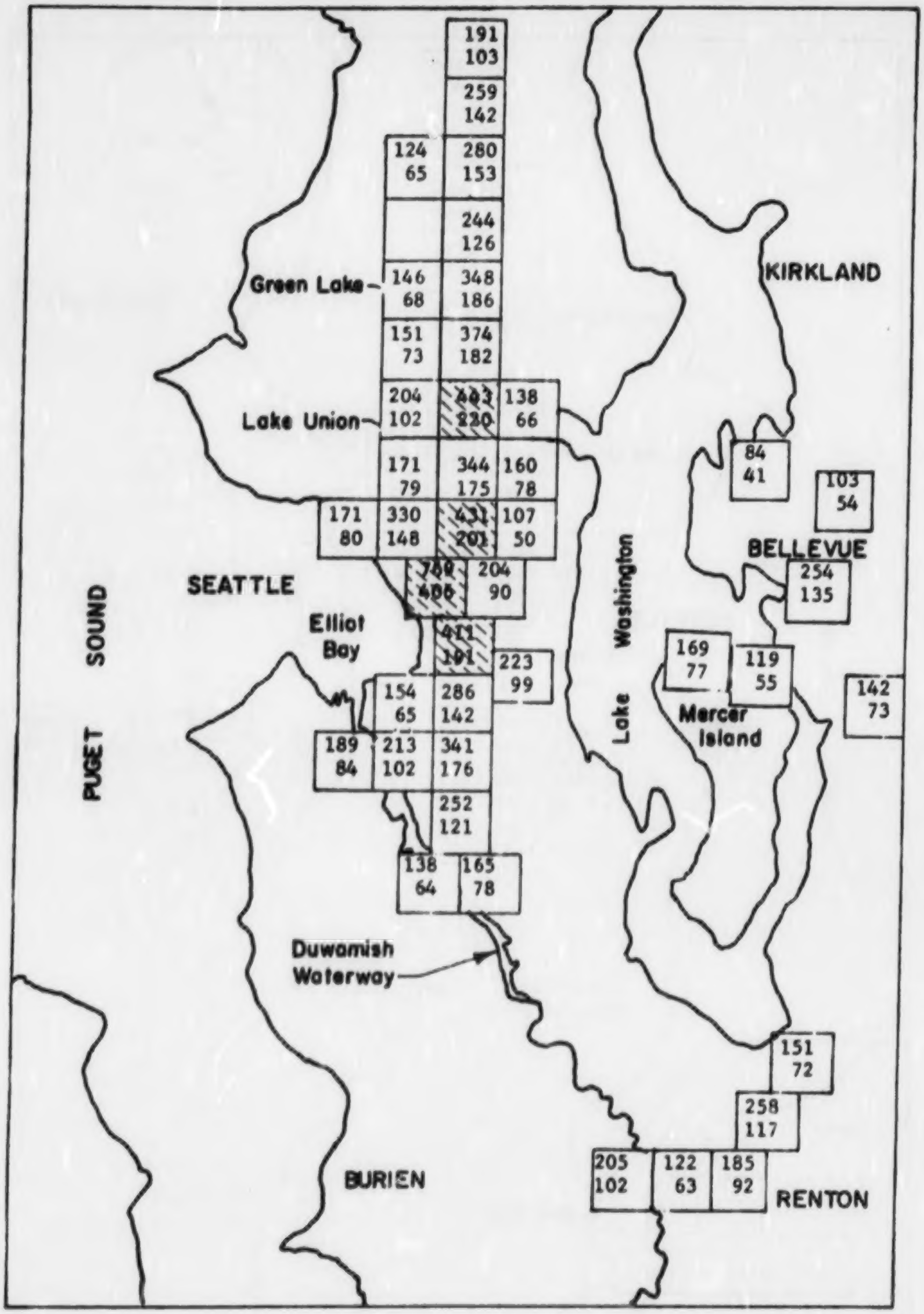


Figure 36. Hydrocarbon emission densities in Seattle for 6 a.m. to 9 a.m. period (Kam/sq. mi.).

Note: Upper values are for 1971, lower values are 1977 emissions based on Federal Motor Vehicle Control Program current as of December 1972.

Source: Reference 23, p. II-67.

Table 61. 1971 CO and HC emissions and concentrations in the Seattle CBD area.

	CO	HC
EMISSION RATES	(Tons/8 hr/1 mi^2)	(Tons/3 hr/23 mi^2)
Vehicular	3.244	1.432
Non-vehicular	.066	.506
TOTAL	3.310	1.938
AIR QUALITY	(8 hr average—ppm)	(1 hr average—ppm)
Observed	20	0.11
National standards	9	0.08
IMPLIED MAXIMUM ALLOWABLE EMISSION RATE	(Tons/8 hr/1 mi^2)	(Tons/3 hr/23 mi^2)
Vehicular	1.42	.93
Total	1.49	1.43

NOTE: (1) CO emissions are 8 hour averages for the 1 square mile area represented by Zone 21.
(2) HC emissions are 3 hour peak period averages for the 23 square mile area of the central city.

Based on Reference 23.

would have reduced CO emissions 43.4 percent and HC emissions 51 percent by 1977*. Thus the HC standards would easily be met by then with the program, while CO emissions would take another two years to attain the standards. These trends are projected in Table 62. Figure 37 presents a graphic picture of CO emissions in the CBD under these trends as well as the possible impact of four transportation control strategies:

- further development of METRO Transit to absorb growth in trip demand;
- development of fringe parking area with PRT links to the downtown;
- improvements and computerization of the traffic signal system; and
- exclusion and removal by incentive of the older, pre-controlled vehicles from the traffic stream.

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*The postponement of the 1975 standards until 1976 does not drastically change the calculations, except that the 1977 estimates are more representative of 1978, the 1978 estimates of 1979, and so on.

Table 62. Projections of CO and HC emissions in the Seattle CBD under the Federal Motor Vehicle Control Program as of December 1977.

	CO			HC
	1977	1978	1979	1977
EMISSION RATES	(Tons/8 hr/1 mi^2)			(Tons/3 hr/23 mi^2)
Vehicular	1.85	1.57	1.36	1.85
Total	1.92	1.64	1.42	.07
AIR QUALITY	(8 hr average—ppm)			(1 hr average—ppm)
Estimated	11.6	9.9	8.6	<0.08
National standards	9.0	9.0	9.0	0.08

Source: Reference 23.

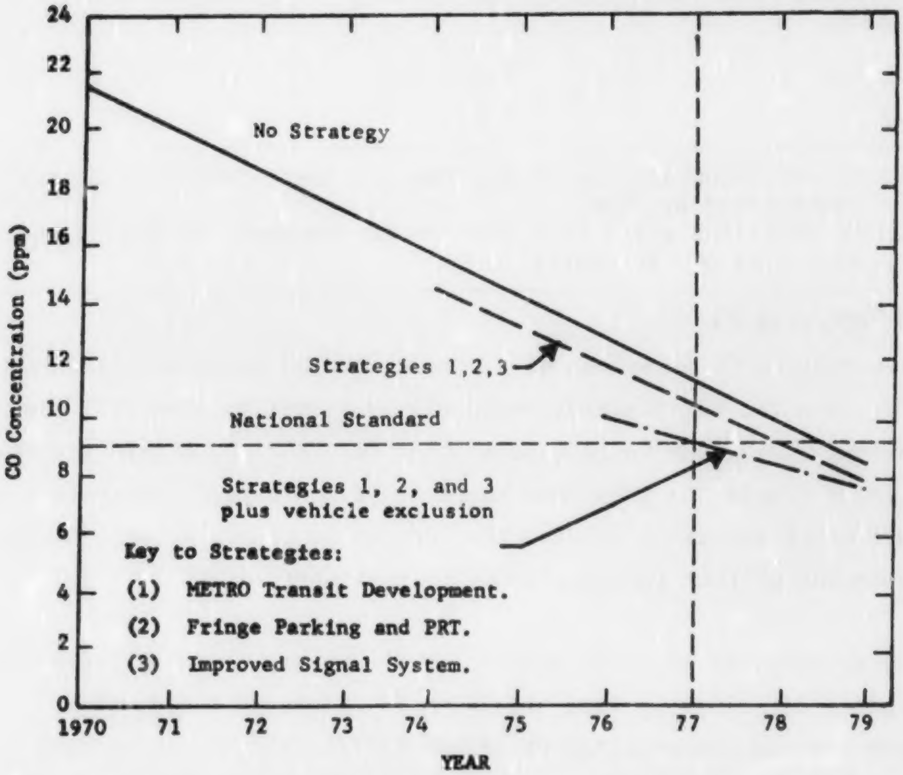


Figure 37. Projected 8-hour CO concentration in Seattle CBD based on 1971 data.

Source: Reference 23, p. VI-3.

BALTIMORE

Introduction

The Baltimore Standard Metropolitan Statistical Area (SMSA) encompasses Baltimore City and the five Maryland counties of Anne Arundel, Howard, Carroll, Baltimore, and Harford. This area, shown in Figure 38, corresponds exactly to Area III of the six intrastate air quality control areas monitored by the Maryland Bureau of Air Quality Control (BAQC).

The Baltimore Metropolitan Area Transportation Study (BMATS) region, which covers some 777 square miles in and around Baltimore City and was first used for regional transportation studies in 1962, provides a convenient point of departure for studying the impacts of transportation on air pollution in Baltimore. This was the region used by the CGA Corporation in its 1972 study Transportation Controls to Reduce Motor Vehicle Emissions in Baltimore, Maryland (26).

For analysis purposes, the BMATS region has been divided into three areas, shown in Figure 39: a central area, the urban fringe, and a suburban ring. The central area includes the 0.554 square mile CBD and the BMATS Districts immediately surrounding it (Figure 40). The urban fringe extends beyond the city limits of Baltimore City to overlap essentially the area within the Baltimore Beltway. The suburban ring covers the rest of the BMATS region. A comparison of the areas of the various regions referred to in this discussion of Baltimore is given in Table 63. Population projections for the various regions are given in Table 64.

Current Status and Future Trends in Congestion

The results of a recent unpublished analysis of existing and projected congestion in the Baltimore City region are given in Table 65. According to this analysis, congestion is expected to remain at its current level—about 25 percent of the trips made during peak travel periods is subjected to congested conditions—until 1980, and then to diminish rather markedly by 1995 due to anticipated extensions to the roadway system.

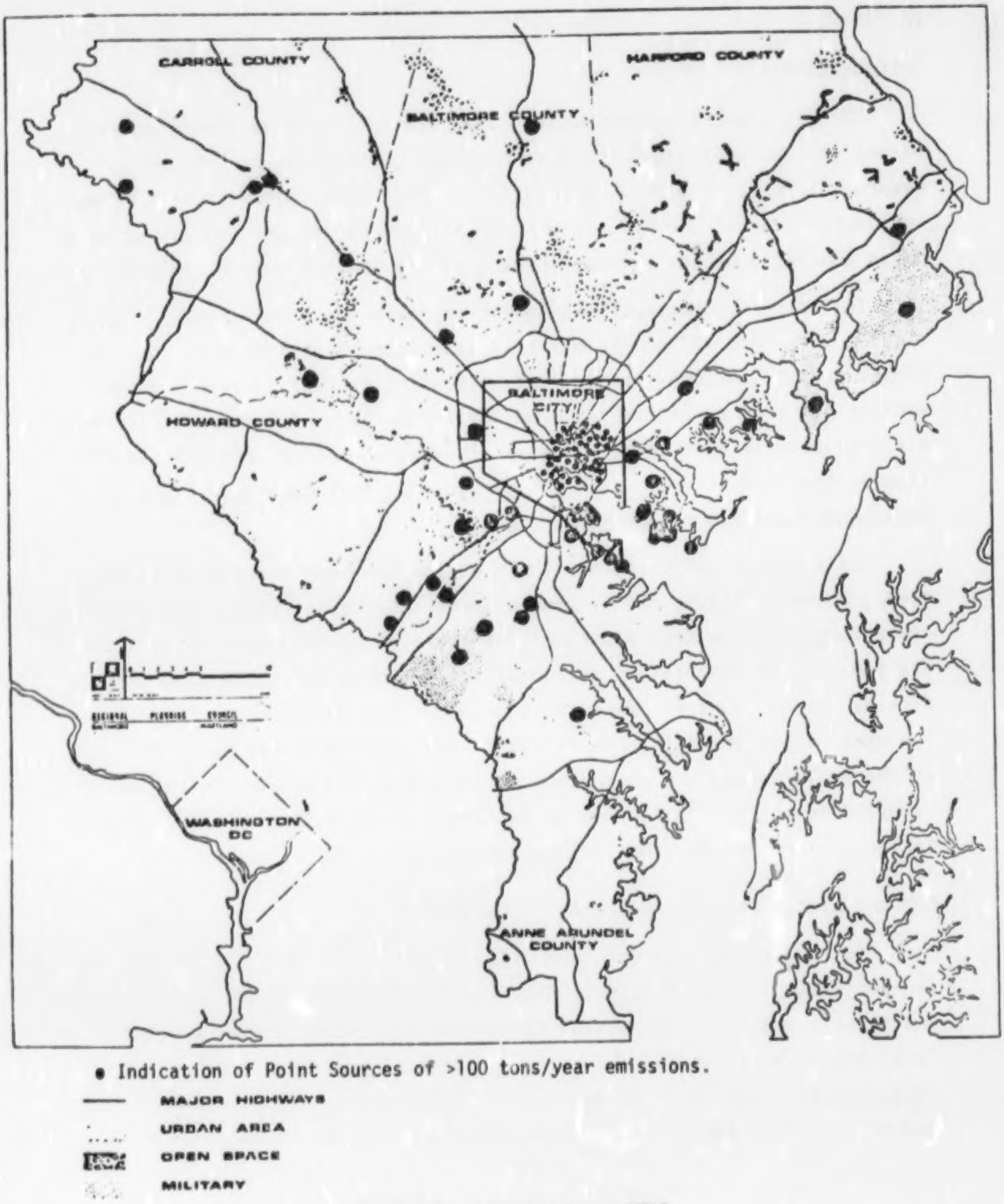


Figure 38. The Baltimore SMSA.

Source: Reference 25, p. 55.

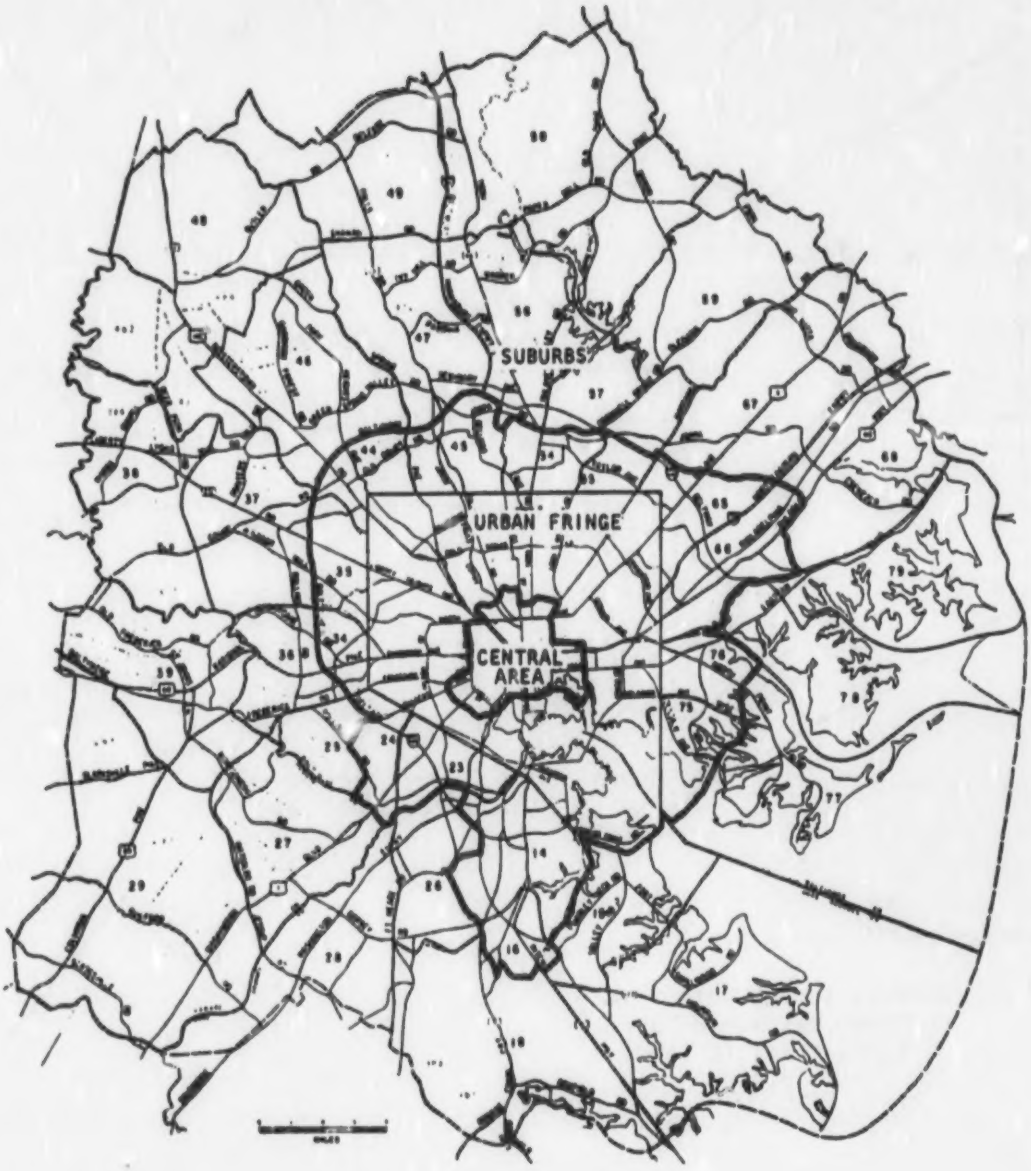
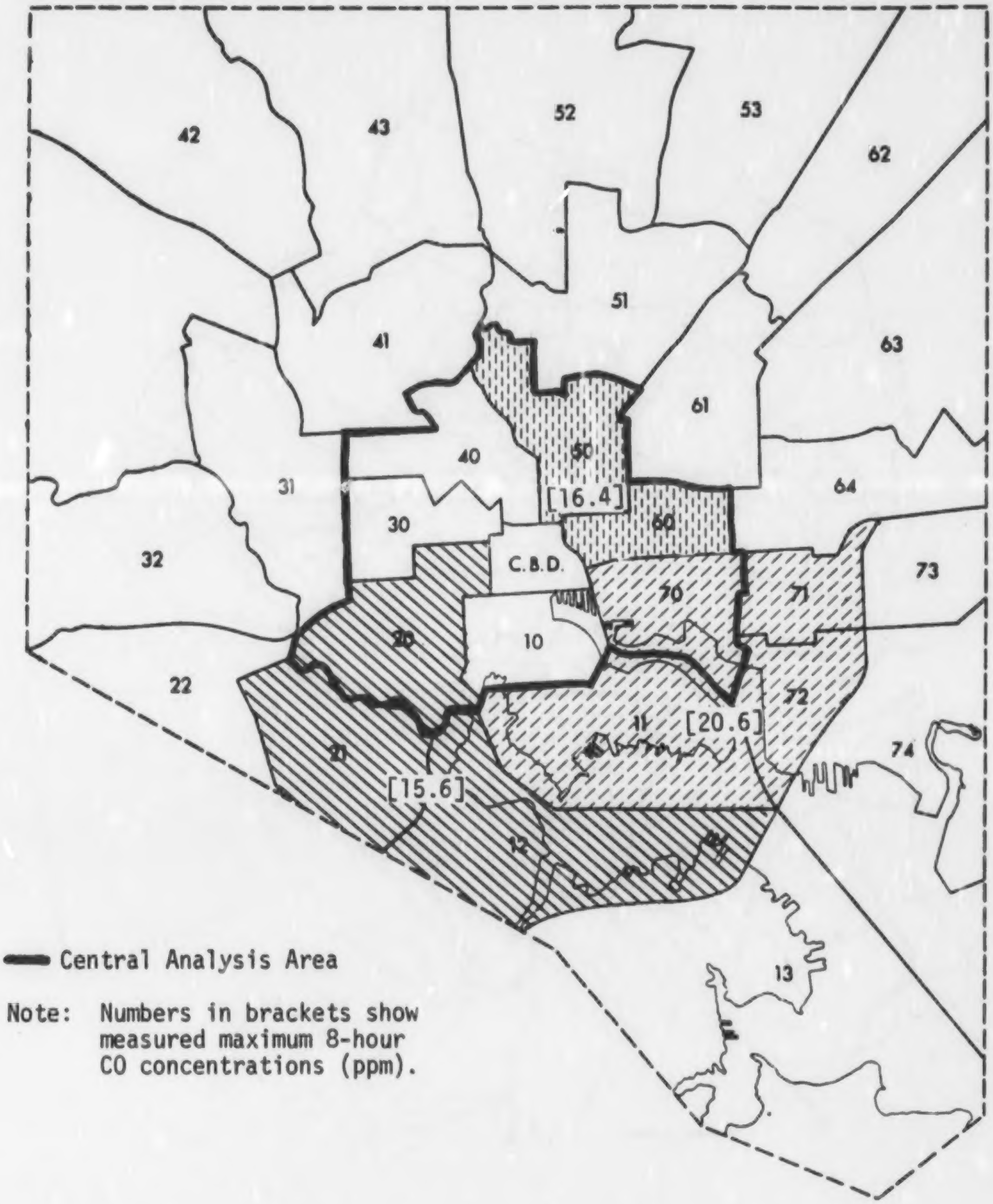


Figure 39. Baltimore analysis areas within the Baltimore Metropolitan Area Transportation Study (BMATS) region.

Source: Reference 26, p. I-9.



▬ Central Analysis Area

Note: Numbers in brackets show measured maximum 8-hour CO concentrations (ppm).

Figure 40. Baltimore Metropolitan Area Transportation Study (BMATS) Districts—Baltimore City.

Source: Reference 26, p. II-28.

Table 63. Baltimore planning region areas.

	Area (square miles)
BMATS Region	
Central area	10.73
Urban fringe	163.6
Subtotal	174.35
Suburban ring	602.9
Total BMATS	777.13
Baltimore City	78.0
SMSA Urbanized Area	**809.0**
Total SMSA Area	**2259.0**

Table 64. Population projections for Baltimore regions (millions).

Year	Baltimore City	SMSA Urbanized Areas	SMSA
1970	0.91	1.58	2.08
1972	--	1.83	--
1975	--	--	2.24
1980	0.88	2.04	2.40
1990	--	2.30	2.76
1995	0.91	--	--
2000	--	--	3.11

Sources: References 27, 28, 29.

According to Reference 29, the Baltimore City area experienced 5.9 million vehicle-miles per day in 1973 and is expected to experience 6.7 and 7.7 million vehicle-miles per day in 1980 and 1995, respectively.

In the BMATS region (nearly equivalent in size to the urban area of the Baltimore SMSA) 17.8 million vehicle-miles per day were experienced in 1973. Travel is expected to grow in this region to 25.6 million

Table 65. Projected congestion impacts on highway person trips in terms of percentage of trips experiencing levels of service D, E or F for Baltimore City.

	1970	1980	1995
Percent of daily person trips	17	17	6
Percent of peak period person trips	24	26	16

Source: Maryland Department of Transportation.

vehicle-miles per day in 1980 and to reach 28.6 million vehicle-miles per day by 1995 (29). Data on the existing and projected temporal distribution of this traffic by vehicle type is given in Table 66.

According to Table 66, no change is expected through 1977 in the temporal distribution of traffic, 10 percent of the total traffic occurring in the peak hour and 75 percent in the 12 daytime hours. Some shift in distribution of traffic by vehicle type, however, is noted, with a greater proportion of heavy duty and diesel vehicles being expected.

Table 66. Vehicle-miles traveled data for BMATS region used for transportation controls study (millions of VMT).

	Peak Hour	12 Hour	24 Hour	Distribution
1970				
Light duty vehicles	1.483	11.125	14.834	.889
Heavy duty vehicles	.166	1.242	1.656	.099
Diesel	.020	.150	.200	.012
TOTAL	1.669	12.517	16.690	1.0
1977				
Light duty vehicles	1.741	13.058	17.410	.860
Heavy duty vehicles	.253	1.898	2.530	.125
Diesel	.031	.229	.306	.015
TOTAL	2.025	15.185	20.247	1.0

Source: Reference 26.

Data and projections on motor vehicle travel for the urban areas of Baltimore SMSA are given in Table 67. Unfortunately, the projections for average speed given in Table 67 are not translatable into measures of the levels of service anticipated (see Section 2), since these measures are based on actual speeds encountered during peak periods. Broadly, however, since the average speed on all functional systems except the Interstate is expected to remain the same or increase, it would appear that no significant increase in congestion is anticipated on these systems. Some decrease in average speed on the Interstate is expected, but it is not possible to interpret this value in terms of increased degree of congestion expected. The existing and projected length and capacity of the roadway system in the urban areas of the Baltimore SMSA are shown in Table 68.

To obtain a rule-of-thumb indication of the roadway investment costs which are likely to be incurred to accommodate the travel projections of Table 67, the annual incremental investment cost per annual incremental vehicle-miles estimator developed in Section 2 can be applied. An increase in daily vehicle-miles of 24.29 million from 1972-1990 is projected, or a total of 8,865 million vehicle-miles for the 18-year-period—an average annual increase of about 490 million vehicle-miles. Assuming an average annual incremental cost per vehicle-mile of $0.018, an annual incremental cost of $8.82 million is implied. The cumulative incremental cost for increases in vehicle-miles over the next 20 years then becomes about $1.7 billion.

If this calculation is performed using the estimated incremental cost for new urban roadway construction and rights-of-way of $0.0087, derived in Section 2, the average annual incremental cost becomes $4.26 million (490 million × 0.0087). The result is a 20-year cumulative cost of $810 million, which represents the estimated sum required solely for new roadway construction and rights-of-way in Baltimore over the next 20 years to accommodate anticipated increases in travel of some 9 billion vehicle-miles. This value of $810 million, then, provides a basis for comparing

Table 67. Data and projections of traffic on the highway system within urban areas of Baltimore SMSA.

	Daily Travel (10^6 VMT/day)			Fraction of Daily VMT			Average Speed (mph)		
	1972	1980	1990	1972	1980	1990	1972	1980	1990
Functional Classification:									
Interstate	4.43	7.12	9.20	.207	.227	.201	55.0	49.1	49.7
Other principal arterials	11.22	16.44	25.10	.524	.524	.549	25.0	28.0	28.0
Minor arterials	2.67	4.16	6.80	.125	.133	.149	20.0	23.0	23.0
Collectors	1.27	1.62	2.25	.059	.052	.049	20.0	20.0	20.0
Local	1.82	2.01	2.36	.085	.064	.052	14.0	14.0	15.0
TOTAL	21.41	31.36	45.70	1.0	1.0	1.0	25.0	27.6	27.6
Design Type:									
Freeways	5.78	11.62	19.34	.270	.370	.423	54.9	49.2	50.1
Other 4 or more lanes	9.95	12.36	16.65	.465	.394	.364	23.9	26.5	24.9
Less than 4 lanes (non-local)	3.86	5.36	7.35	.180	.171	.161	18.9	18.5	17.0

Source: Reference 28.

Table 68. Data and projections on length and capacity of the highway system within the urban areas of Baltimore SMSA.

	1972	1980	1990
Length of Route (miles)			
Interstate	94	113	115
Other principal arterials	581	626	749
Minor arterials	590	590	613
Collectors	485	485	490
Local	4,089	4,349	4,736
TOTAL	5,839	6,163	6,703
Freeways	135	189	296
Other 4 or more lanes	419	471	588
Less than 4 lanes (non-local)	1,196	1,154	1,083
Capacity Miles (10^3 vehicle miles/hour)			
Interstate	564	684	842
Other principal arterials	1,120	1,405	2,036
Minor arterials	529	595	772
Freeways	688	1,018	1,522

Source: Reference 28.

the projected investment costs for alternative strategies designed to reduce congestion, air pollution and energy use in the Baltimore area in conjunction with their tradeoffs in terms of concomitant social benefits and costs.

Air Pollution

The Baltimore transportation controls study (29) identifies CO and oxidant-related HC emissions as providing difficulties for the area in its effort to attain the national air quality standards. An inventory of CO and HC emissions for the Baltimore BMATS region in Table 69 indicates that 83 percent of the CO emissions in 1970 and 55 percent of the HC emissions can be attributed to motor vehicles. Projections for 1977, also shown in this Table, indicate that the proportion of emissions due to motor vehicles ought to drop to 72 percent for CO and 46 percent for HC, due to the current Federal Motor Vehicle Emission Control program.

Table 69. Summary of 1970 and 1977 air emission inventories for BMATS region.

SOURCE	CO				HC			
	1970		1977		1970		1977	
	Tons/Day	Percent	Tons/Day	Percent	Tons/Day	Percent	Tons/Day	Percent
Motor Vehicles								
Light duty vehicles	997	66.8	379	43.7	156	42.6	52	25.0
Heavy duty vehicles	226	15.1	241	27.8	44	12.0	42	20.2
Diesel	5	.3	7	.8	0.7	.3	1	.5
Subtotal	1228	82.4	626	72.3	201	55.0	95	45.7
Aircraft	48	4.4	58	9.2	23	6.3	8	3.8
Shipping (other than diesel trucks and buses)	21	1.9	21	3.7	5	1.4	6	2.8
Non-mobile Sources	123	11.3	93	14.8	136	37.3	99	47.7
TOTAL	1491	100.0	866	100.0	366	100.0	208	100.0

Source: Reference 26.

Non-vehicular emission sources in the Baltimore area, unlike those in many urban areas, were responsible for a significant proportion of CO and HC emissions. Therefore, in the case of Baltimore, the success with which these non-vehicular emissions can be controlled will have an impact on the pressure for controlling motor vehicle emissions if maximum allowable emission goals cannot be met.

The maximum allowable emissions from all sources were determined by relating maximum concentrations of observed emissions to the proposed rollbacks. These allowable emissions are:

CO — 3.39 tons per square mile per day; and

HC — 20.1 tons per three hours during the daily peak period.

Projections of CO emissions distributed among types of sources in the three BMATS analysis regions are given in Table 70, and projections of peak period HC emissions among types of sources are given in Table 71. To recapitulate points made repeatedly in emissions analyses for other cities, CO is directly detrimental to health, and since it is emitted as a result of the combustion process, tends to be concentrated in areas of high activity. HC emissions, on the other hand, undergo oxidation and action by the sun before they become detrimental to health, and hence are dispersed over a wide area while undergoing these changes. This is the rationale for breaking down the analyses of CO emissions by regions closely related to activity, and continuing the HC emissions analyses on a region-wide basis.

From the projections in Tables 70 and 71, it appears that most emission goals will be met by 1977 with the exception of CO emissions in the central area, which are expected to be 58 percent above allowable levels. If emissions from non-vehicular sources can be controlled to some extent—and it has been stated that this may prove difficult in the Baltimore area because of the nature of these sources—allowable levels may eventually be reached. Supplementary projections for emissions by motor vehicles alone, given in Table 72, show a continuing and significant drop in emissions from this source for 1980, 1990, and 1995.

Table 70. Distribution of 1970/1977 daily motor vehicle and other distributed source emissions (tons/day) among analysis regions and types of vehicles for the BMATS region.

SOURCE	Central Area	Urban Fringe	Suburban Ring	Total BMATS Region	Distribution among Motor Vehicle Sources
1970					
Motor vehicles	119.5	671.6	437.2	1228.2	
Other distributed sources*	2.1	11.2	81.3	94.6	
TOTAL	121.6	682.8	518.4	1322.8	
1977					
Light duty vehicles	33.4	189.3	156.1	378.8	.605
Heavy duty vehicles	21.2	120.1	98.9	240.2	.384
Other	.6	3.4	3.2	7.1	.011
Total Motor Vehicles	55.2	312.7	258.2	626.1	1.0
Other distributed sources*	2.4	12.9	93.2	108.4	
TOTAL	57.6	325.6	351.4	734.5	
Maximum Allowable Emissions**	36.4	554.9	2045.0	2636.3	

*Does not include all non-mobile sources.
**Based on maximum of 3.39 tons/mi^2/day.

Source: Reference 26.

Table 71. **Distribution of 1970/1977 peak period (6-9 a.m.) HC emissions (tons/3 hrs.) from motor vehicle and other sources for the BMATS region.**

SOURCE	1970	1977	Distribution among Motor Vehicle Sources
Motor Vehicles			
Light duty vehicles		13.0	.544
Heavy duty vehicles		10.6	.444
Diesel		.3	.012
Subtotal	50.2	23.9	1.0
Shipping (other than diesel trucks and buses)	.6	.7	
Aircraft	2.9	.9	
Non-mobile Sources	11.1	7.9	
TOTAL	64.9	33.4	
Allowable Emission*	20.1		
***Assuming a 69 percent rollback.**			

Source: Reference 26.

Table 72. Supplementary baseline projections of air pollutant emissions in Baltimore due to motor vehicles alone (tons/day).

A. BMATS baseline projections.

	Inside Beltway*			Outside Beltway			BMATS Region		
	1972/73	1980	1995	1972/73	1980	1995	1972/73	1980	1995
CO	618.1	181.3	87.1	392.4	160.9	82.0	1010.5	342.2	169.1
HC	126.9	26.4	14.1	74.4	21.3	12.5	201.3	47.7	26.6
NO_x	59.9	27.7	14.2	44.7	27.2	13.4	104.6	54.9	27.6
Particulates	3.2	1.5	1.7	2.3	1.4	1.6	5.5	2.9	3.3

*Approximately equivalent to central area plus urban fringe area.

Source: Reference 29.

B. Baltimore SMSA urbanized area under currently planned improvements (tons/day).

	1972	1980	1990
CO	1616	848	338
HC	157	125	23
NO_x	287	114	37

Source: Reference 28.

SUMMARY

The four cities studied possess a common problem in meeting carbon monoxide (CO) ambient air quality standards by 1977 given the current federal motor vehicle emission control program. The vast proportion of CO pollution is attributed to motor vehicles: this proportion ranges from 76 to 97 percent of total CO emissions in 1977 in the four cities. In all of these cities, the maximum CO concentrations are expectedly associated with the areas of greatest activity such as the CBD. UMTA may have an important role in controlling concentrations of CO, since these concentrations are associated with the areas immediately adjacent to arterials and freeways in highly traveled corridors of the urban area, which are best suited to public transportation.

Two of the cities—Los Angeles and Baltimore—will not be able to meet HC ambient air quality levels; the other two will. In Los Angeles, local meteorological and topographic conditions are such that the standards for HC cannot be achieved by controlling transportation emissions, even to the point of stopping all vehicular traffic. Nor will Los Angeles be able to attain the NO_x ambient air quality standards by 1977, given the current federal motor vehicle emission program.

Summaries of the emission analyses for all four cities are given in Tables 73 through 76. The tables give estimated percentages of total emissions attributable to all motor vehicles and to light duty vehicles alone for baseline years and for 1977. The percentage attributable to light duty vehicles identifies the maximum possible impact that a shift from private personal transportation to pollution-free public transportation modes might have on air quality.

Meeting the EPA standards by 1977 for the four cities, given the current federal emission control program, implies the following estimated rollback of light duty vehicle activity:

Los Angeles : 74 percent for CO
>100 percent for HC
40 percent for NO_x
Seattle CBD : 31 percent for CO

Table 73. Summary of air pollutant emission analyses for the Los Angeles area.

Measurement/Prediction	CO	Highly Reactive HC	NO_x
Percent of total 1970 emissions by:			
all motor vehicles	96	83	81
light duty vehicles	85	74	65
Percent of total 1977 emissions by:			
all motor vehicles	92	68	71
light duty vehicles	74	56	43
Maximum allowable emissions as percent of total emissions in:			
1970	22	9	53
1977	45	17	83
Year air quality goals expected to be met under current motor vehicle programs	c.1982	Never	c.1981
Percent rollback required on all emissions in:			
1977	55	83	17
1990	None	77	None
Percent of light duty vehicle emissions matching rollback requirements in 1977	74	148 (>100%)	40
Area of maximum concentration in 1977	CBD	High Activity Coastal Zone	High Activity Coastal Zone

NOTE: Percentages have been computed on the basis of emissions and maximum allowable emissions adjusted for the effects of speed.

Table 74. Summary of air pollutant emission analyses for the city of Seattle.

Measurement	CO	HC
Percent of total 1970 emissions in King County by:		
all motor vehicles	96	77
light duty vehicles	83	60

Measurement/Prediction	CO in CBD	Peak Hour HC Citywide
Percent of total 1970 emissions by:		
all motor vehicles	98	76
light duty vehicles	85	45
Percent of total 1971 emissions by:		
all motor vehicles	98	74
light duty vehicles	84	61
Percent of total 1977 emissions by:		
all motor vehicles	97	58
light duty vehicles	75	41
Maximum allowable emissions as percent of total emissions in:		
1970	42	68
1971	45	74
1977	78	119*
Year air quality goals expected to be met under current motor vehicle programs	c.1979	c.1975
Percent rollback required on all emissions in 1977	23	None
Percent of light duty vehicle emissions matching rollback requirements in 1977	31	N/A

*Emission less than maximum allowable.

Table 75. Summary of air pollutant emission analyses for the city of Philadelphia.

Measurement/Prediction	City of Philadelphia	Philadelphia Air Quality Control Region		
	CO	CO	HC	NO_x
Percent of total 1971 emissions by:				
all motor vehicles	86	69	54	27
light duty vehicles	77	62		
Percent of total 1977 emissions by:				
all motor vehicles	76	55	44	23
light duty vehicles	63	63		
Maximum allowable emissions as percent of total emissions in:				
1970	44	31	52	42
1977	75	55	107	42
Year air quality goals expected to be met under current motor vehicle programs	c.1978	c.1985	c.1976	Minor impact of motor vehicles on problem
Percent rollback required on all emissions in 1977	25	45	None	58
Percent of light duty vehicle emissions matching rollback requirements in 1977	39	71	N/A	N/A

Table 76. Summary of air pollutant emission analyses for the Baltimore area.

Measurement/Prediction	Central Area	BMATS Region		
	CO	CO	HC	Morning Peak HC
Percent of total 1970 emissions by:				
all motor vehicles	98	82	55	77
light duty vehicles	80	67	43	50
Percent of total 1977 emissions by:				
all motor vehicles	96	72	46	72
light duty vehicles	58	44	25	39
Maximum allowable emissions as percent of total emissions in:				
1970	30	199*	--	31
1977	64	359*	--	60
Year air quality goals expected to be met under current motor vehicle programs	c.1980	--	--	?
Percent rollback required on all emissions in 1977	36	None	--	40
Percent of light duty vehicle emissions matching rollback requirements in 1977	62	N/A	--	102 (>100%)

*Emissions less than maximum allowable.

City of Philadelphia : 39 percent for CO
Baltimore Central Area: 62 percent for CO
BMATS Region : >100 percent for morning peak HC

Attainment of such goals is impracticable. The alternatives, of course, are to delay the required attainment of the standards, to further reduce pre-1976 automotive emission control standards, or to further control emissions from other sources.

In most cases, the current federal exhaust emission program should be sufficient to allow the attainment of ambient air quality standards by the mid-1980s. (The HC problem noted as possibly existing in the Baltimore area in 1980 is not related to light duty motor vehicles as much as it is to non-mobile sources.) The exception to this reassuring generalization is the attainment of the HC standard in Los Angeles. Under current programs, in 1990 a 77 percent rollback will still be needed to attain acceptable air quality. This is a problem which needs to be studied in greater depth. Alternatives such as all-electric transportation systems, though not completely sufficient to remedy the problem, are not out of the question.

A bird's-eye summary of the automobile-related congestion and pollution problems in the four areas studied is presented in Table 77 along with data on population and motor vehicle travel which illustrates the great diversity of the four cities examined. Some of the entries are order-of-magnitude estimates. Estimates of current congestion levels are difficult enough to make; projections of congestion are even more so.

A general increase is projected in congestion levels. In most cases, the amount of congestion will increase in areas outside the central cores, as will the proportion of vehicle-miles traveled there. Thus proportions of vehicle-miles traveled in congested conditions may well stay about the same as during this decade. This is the basic projection for Los Angeles, Seattle, and the BMATS region. Philadelphia and the central area of Baltimore vary somewhat from this pattern. A current extensive effort to reduce congestion within the city of Philadelphia is likely to be effective, but rapid growth in areas outside of the city may eventually offset this

Table 77. Comparison of congestion and pollution in the four urban areas studied.

					CONGESTION				POLLUTION				
Urban Area	Population (millions)		Daily Motor Vehicle Travel (millions VMT/day)		Percent Daily VMT (1970)	Percent Peak Period VMT (1970)	Projected Trends For		Percent of Total Emitted by Light Daily Vehicles (1970)			Problems Expected In	
	1970	2000	1970	2000			Near Term (1980)	Long Term (1990)	CO	HC	NO_x	Near Term (1980)	Long Term (2000)
Los Angeles: LARTS/ 5 counties	10.0	16.0	145	258	~9	~19	Increase on non-freeway arterials, some elsewhere.	About the same as 1980.	85	74	65	HC a problem.	HC a problem; NO_x may become a problem again.
Seattle: Central Area	0.5	~0.6	5.8		~1	~11	Increase.	Return to about the same as 1970.	85	49		None.	None.
SMSA	1.4	2.5	22	~36	~0.3	~3	Slight increase.	About the same as 1980.	83	60	~55	None.	None.
Philadelphia: SMSA	4.8	6.8	58	~115	~2		Decrease.	Increase to greater level than 1970.	77	<50	<30	None.	None.
Baltimore: Center City	.9	.9	5	~8	4.3	43	Increase.	Slight decrease from 1980 levels	80	~47		None.	None.
BMATS	1.6	~2.7	17	~30	~1.8	18	Slight increase.	About the same as 1980.	67	43		HC may still be above standards in some areas.	None.

gain. The Baltimore City projection is implied by the computer model simulation discussed in the Baltimore section which projects an increase in congestion in the urban fringe area immediately outside of the central area. In both Philadelphia and Baltimore, the areas affected could certainly be served by a well-developed urban area public transportation system.

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SECTION 4

EPA, UMTA AND FEDERAL ENERGY GOALS, AUTHORITY AND PROGRAMS AND PRELIMINARY TREND IMPLICATIONS FOR FEDERAL GOALS

INTRODUCTION

In order to analyze the implications of the trends in congestion, pollution, and energy use on federal air quality and urban transportation goals, and to identify actions which EPA and UMTA might take, the agencies' authorities, goals, and programs in these areas must be known. A knowledge of the agencies' goals is needed to define areas of common interest. A review of existing programs can show what is already being done to counteract unfavorable trends, and can pinpoint opportunities for immediate joint action based on already ongoing activities. An understanding of the agencies' authorities as defined by both legislation and practice will indicate how interagency programs may be structured to make the most effective use of each agency's powers.

Thus this section provides a basis for evaluating the impacts of the trends described in Sections 2 and 3, and lays the groundwork for the identification of trend-offsetting phenomena in Volume 1.

While this section focuses primarily on federal-level goals, jurisdiction, programs, achievements, and problem areas, some attention is given to the status of state and local programs and legal authority in the four urban areas which are used as case studies in this report: Los Angeles, Seattle, Baltimore, and Philadelphia. An understanding of the major differences in emphasis between federal and lower-level goals and programs will be important in identifying the appropriate level of government where action should be taken to promote the offsetting phenomena inventoried in Volume 1.

In keeping with the overall scope of the study, this section will cover the goals and programs associated with the Urban Mass Transportation Act, but will be concerned only with the air quality legislation, goals and programs which affect motor vehicle emissions. Thus the control of emissions from stationary sources and aircraft are not discussed, and the national ambient air quality standards are presented as they relate to the motor vehicle emission

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requirements. Proposed energy goals and programs will be only briefly described, since the federal energy agencies have been created only very recently and their programs and goals are still in the formative stages.

BASIC FACTS ABOUT EPA AND UMTA

Enabling Legislation

Both the Environmental Protection Agency, an independent regulatory agency, and the Urban Mass Transportation Administration, one of the seven administrations within the Department of Transportation, were formed by Presidential reorganizations which consolidated several units from other agencies. In UMTA's case, the goals of the new administration had been expressed in earlier legislation; in EPA's case, the scope of the earlier legislation was greatly extended in new legislation which became effective in the same month as the reorganization plan.

UMTA was created in June 1968 by the same organization plan which transferred the functions of the Department of Housing and Urban Development under the Urban Mass Transportation Act of 1964* to the Department of Transportation (5 U.S.C. Reorg. Plan of 1968 No. 2). EPA was created in December of 1970 to bring together in a single agency, federal activities in controlling air and water pollution, drinking water quality, solid wastes, pesticides, environmental radiation, and noise (5 U.S.C. Reorg. Plan of 1970 No. 3). It was created to carry out the provisions of the Clean Air Act.**

Structure and Budget

EPA's structure is highly decentralized in comparison to UMTA's, its air quality staff five times the size of UMTA's total manpower, and its budget more than twice as large. Of EPA's 8,000 employees, 6,000 are assigned to the 10 regional offices and laboratories. Of the 8,000, about 1370 are directly associated with air quality activities (R&D, abatement and control, and enforcement).

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*P.L. 88-365, 78 Stat. 302, 49 U.S.C. 1601 (Reference 1).

**42 U.S.C. 1957 et seq. Includes several Public Laws from 1963 to 1970 (Reference 2).

The agency's budget for FY 1973 was about $2.5 billion, of which about $2 billion was earmarked for the construction of sewage treatment facilities and for assistance to localities in sewer design and construction. The operating budget for 1974 is about $450 million, of which about $146 million is earmarked for air quality programs. This compares with $151 million in FY 1973 and $109 million in FY 1971, the program's first year.

UMTA's structure has until recently been highly centralized, with 230 of its 260 employees in Washington. Regional offices are gradually being staffed, and an increase of 100 employees, 11 in the field offices, has been requested for 1974. UMTA's 1973 budget was $980 million; $1 billion has been requested for 1974. Nearly 90 percent of these funds is distributed to states and localities in the form of capital grants to purchase equipment, as technical studies grants for urban transportation planning, and as research and training grants, leaving about $73 million for R&D. While UMTA spent in 1973 $16 million more for transit R&D than EPA spent for air quality R&D, UMTA needs no funds nor personnel for abatement, control, and enforcement. Thus its operating budget and staff are much smaller than EPA's (Reference 3, pp. 667-732, "Justifications").

GOALS

The legislation which the two agencies must carry out lists for each the broad purposes to which it should direct its effort.

PURPOSES OF URBAN MASS TRANSPORTATION ACT	PURPOSES OF CLEAN AIR ACT
1. Develop improved mass transportation facilities, equipment, techniques, and methods.	1. Protect and enhance the quality of the nation's air resources to promote public health, welfare, and productive capacity.
2. Encourage planning and establishment of areawide urban mass transportation systems needed for economical and desirable urban development.	2. Initiate and accelerate a national research and development program to prevent and control air pollution.
3. Provide assistance to state and local governments in financing such systems.	3. Provide technical and financial assistance to state and local governments in developing and executing air pollution prevention and control programs.
	4. Encourage and assist development and operation of regional air pollution control programs.

The purposes of both agencies include R&D, financial aid to states and localities, and promotion of areawide or regional programs. However, there is a fundamental difference in the orientation of the enabling legislation which is reflected in the two agencies' structures, budgets, and accomplishments: EPA is required to quantify and enforce its goals, while UMTA is not.

EPA Goals

EPA is required by the Clean Air Amendments of 1970 (P.L. 91-604) to promulgate specific standards and take other regulatory action within specifically stated time periods following the enactment of the Act. These requirements and the major actions taken which are relevant to this study are summarized in Table 78. The actual values of the national ambient air quality standards and the vehicle emission standards for gasoline-powered light duty motor vehicles (passenger cars seating 12 or fewer) are shown in Tables 14 and 15 in Section 2 (p. 41). Vehicle emission standards have also been promulgated for diesel light duty vehicles, light duty trucks, and engines for use in heavy duty vehicles, both gasoline and diesel-powered.

The auto emission reduction goals were stipulated in the Act before the ambient air quality standards were established, and are not derived from them. The air quality standards, however, are based on scientific testing of levels of the major pollutants which would affect the public health (primary standards) and the public welfare (secondary standards). The definitions of public health and welfare cited in Section 2 (pp. 36 and 42) may be taken to be two of the primary goals of the 1970 Clean Air Act; the other primary goal is to "clean up" auto emissions. These goals remain valid even though specific EPA-promulgated standards may be suspended or modified and time deadlines may be pushed back by further legislation.

UMTA Goals

UMTA's goals, in legislation and in practice, have been qualitative rather than quantitative. The most progressive statement of UMTA's goals is that made by UMTA Administrator Frank C. Herringer before the House Appropriations Committee in March 1973 (3, p. 629).

Table 78. Major EPA and state actions required by the Clean Air Act, and summary of actions taken.

Action Required	Time Period Allowed	Action Taken
TITLE I: AIR POLLUTION PREVENTION AND CONTROL		
By EPA Administrator:		
(1) Sec. 108. Publish and periodically revise a list of air pollutants.	Within 30 days after enactment of Act.*	Current list includes particulate matter, sulfur oxides, carbon monoxide, photochemical oxidants, hydrocarbons, and nitrogen oxides. Standards for fluorides, polycyclic organic matter and odorous substances may be proposed in the future.
(2) Issue air quality criteria for an air pollutant, and issue to the states and appropriate agencies information on control techniques and costs.	Within 12 months after pollutant appears on list in (1) above.	Series of reports on air quality criteria and control techniques published beginning in 1967 pursuant to the Air Quality Act of 1967, and revised: sulfur oxides, particulate matter, photochemical oxidants, carbon monoxide, nitrogen dioxide, hydrocarbons.
(3) Sec. 109. Publish proposed regulations prescribing national primary and secondary ambient air quality standards for comment and review.	Within 30 days after enactment of Act.	
(4) Promulgate national primary and secondary ambient air quality standards for each pollutant.	No later than 90 days after (3) above.	Regulations on national primary and secondary ambient air quality standards (NAAQS) promulgated Nov. 25, 1971, and amended Sept. 14, 1973.
By States:		
(5) Sec. 110. Adopt a plan to implement, maintain, and enforce the national primary and secondary ambient air quality standards in each air quality control region.	Within 9 months after (4) above.	State plans for achieving compliance with primary NAAQS have been in effect since early 1973 for all 55 jurisdictions. Plans for achieving compliance with secondary standards were in effect for 37 jurisdictions by mid-1973 and were expected to go into effect for the rest by mid-1974.

Table 78 (continued)

Action Required	Time Period Allowed	Action Taken
By EPA Administrator:		
(6) Approve or disapprove state implementation plans.	Within 4 months after the date required under (5) above.	Initial approvals and disapprovals published by Administrator on May 31, 1972. Others published throughout 1972, 1973, and 1974. Approvals and disapprovals of transportation control plans began June 15, 1973; transportation plans to be approved or revised by mid-1974 for the 29 urban areas required to have them.
(7) Prepare and publish proposed regulations setting forth a state implementation plan if the state does not do so or if the state plan is not in accordance with the requirements.	Within 6 months after the date required under (5) above.	Example: State of California failed to submit transportation control scheme for Los Angeles. EPA proposed regulations to reduce vehicle-miles traveled by 80%. Local hearings concluded in March 1973, EPA promulgated plan in July 1973. Revisions continue as of report date.
TITLE II: EMISSION STANDARDS FOR MOVING SOURCES: PART A, MOTOR VEHICLE EMISSION AND FUEL STANDARDS		
By EPA Administrator:		
(8) Sec. 202. Prescribe and revise standards applicable to the emission of any air pollutant from new motor vehicles, and measurement techniques on which such standards are based.	Within 180 days after enactment of the Act.	Act itself calls for at least a 90% reduction by 1975 of the CO and HC emissions from their values in the 1970 model-year autos, and a reduction of at least 90% by 1976 in NO_x emissions from their measured values in 1971 model cars.**
(9) Sec. 211. The Administrator may designate fuels or fuel additives to be prohibited after a designated date unless registered as to chemical composition and purpose. The Administrator may also prohibit the sale of a fuel or additive if its	Not specified.	Regulations requiring a phased reduction in the lead content of regular and premium gasolines through 1978 have been promulgated. Regulations also promulgated requiring petroleum companies to make available one grade of lead-free and phosphorous-free gasoline by mid-1974.

Table 78 (continued)

Action Required	Time Period Allowed	Action Taken
emission products will endanger the public health or welfare or seriously impair the performance of an emission control device.		

*The Act referred to is P.L. 91-604, the Clean Air Amendments of 1970.

**Earlier controls for HC and CO had reduced emissions by 70 and 60 percent respectively from 1974 levels. Crankcase emissions of HC had been eliminated completely in 1968, and HC evaporative losses from fuel tank and carburetor were reduced in 1971 model-year cars. The 90 percent HC and CO reduction required by the Clean Air Act therefore really represents about a 98 percent clean up from pre-control vehicles.

NOTE: Only those portions of the Clean Air Act are covered which are relevant to air quality standards and to motor vehicle emissions. This includes Title I, Secs. 101-110, 113-117; Title II, Secs. 202-213; and Title III. It does not include the secions of the Act concerning standards of performance for new stationary sources (Title I, Sec. 111); national emission standards for hazardous air pollutants from stationary sources (Title I, Sec. 112); control of pollution from federal facilities (stationary; Title I, Sec. 118); or aircraft emission standards (Title II, Part B).

Source for "Actions Taken": Reference 4.

> "The UMTA assignment is in essence to reinvigorate public transportation in order to provide service that will attract new riders, regardless of their social or economic group or the purpose of their journey . . .. Transportation is not perceived as an end in itself, but as a means to an end, which described broadly is to promote the welfare and vitality of urban areas in keeping with locally determined objectives."

The most precise statement of UMTA's objectives is contained in the excerpt from its external operating manual, which lists the following near-term objectives, not necessarily in order of priority (5):

- Mobility of non-drivers.
- Relief of traffic congestion.
- Improved quality of urban environment.

An UMTA R&D project now in the preliminary stages is seeking to develop a set of quantitative and qualitative measures of transit system performance in terms of the following criteria and impact groups (6):

Transit Performance Criteria

- Accessibility
- Quality of service
- Economic performance
- Impact on urban environment

Transit Impact Groups

- Riders
- Operators
- The public
- Industry

The group of measures specified should help to clarify the terms of the legislation. But for these measures to be put to practical use, goals will also have to be identified and priorities set.

INTERPLAN has postulated UMTA goals in terms of the amounts of public transportation needed by certain target dates (7). The actual figures and dates are meant to be illustrative and are clearly open to criticism. INTERPLAN's estimates are based on the premise that a certain number of urban travelers will have to be transferred from their own automobiles to public and para-transportation modes. This transfer will be gradual—it is beginning already in some cities—and will continue until at least the end of this century when hopefully the "optimum" mix of urban private, public, and para-transportation will have been achieved (see Volume 2 for further treatment of this issue).

Both immediate and do-able, as well as long-range, targets must be set. If for planning purposes the year 2000 is thought of as the long-range target date for a bus or rail seat for every car commuter, then 1978 would be a suitable planning date for the short-range, less ambitious target of doubling 1973 transit ridership. The mid-range target date would then be 1985, and the mid-range goal would be to quadruple 1973 transit ridership. This primitive attempt at quantification is summarized in Table 79.

Table 79. Short- and long-range objectives for transit.

	TARGET AND YEAR			
	1973	1978	1985	2000
Objectives:	Starting point	Double 1973 ridership	Quadruple 1973 ridership	A seat for every auto commuter
Annual number of transit riders (billion):	6	12	24	32
Planning horizon:	Current	Short-range	Mid-range	Long-range

For the moment, UMTA lacks such rigidly defined goals and the legislative power to enforce them. However, even without further legislative powers, UMTA would put itself in a leadership position by proclaiming goals such as these.

The transit industry has already predicted dramatic ridership increases due to the energy crisis. Speaking for the American Transit Association before a Senate Transportation Subcommittee, Cleveland Transit System executive Leonard Ronis said in December 1973 that the energy crisis will add 6.8 million riders in each rush hour (8). Extrapolating this figure to mean 13.6 million more rides every working day, this would add 3½ billion riders annually (250 working days a year), or an increase over the 1973 level of better than 50 percent. At this rate of increase, the 12 billion ridership goal indicated above for 1978 would be attained in less than 2 years. A much lower sustained growth rate of 15 percent a year, including 1973-1974, would be required to attain the 1978 INTERPLAN goal.

UMTA's 1973 survey of the ridership effects of selected capital grants could form the basis for a definition of realistic ridership goals. UMTA Administrator Herringer reported to the House Appropriations Committee in March 1973 that a survey of eight major capital grant cities indicates that ridership has increased from 2 to 20 percent annually over the 2 years surveyed. Further case studies for 20 more cities are being conducted to compare the expected and actual results of the capital grants, as measured by both qualitative opinion and by data collected (3, p. 735). Such surveys would have to be conducted in every city receiving UMTA grant money if criteria similar to INTERPLAN's proposed ridership targets were adopted.

Summary

EPA's and UMTA's goals overlap specifically with respect to decreasing travel by auto in urban areas. UMTA's goal, to promote transit, para-transit, and more efficient auto use through carpooling, is instrumental in attaining EPA's broader, more forcefully legislated goals. In order to protect urban air resources, cities will need improved mass transit facilities, equipment, and techniques, and—which existing legislation deals with only indirectly—these facilities will have to be used by greater numbers of riders.

The emergency energy bill which passed the Senate and House before Christmas 1973 would have called for federally sponsored incentives for the use of public transportation, granting the President the right to impose gas rationing but requiring Congressional approval for other energy conservation measures such as the requiring of carpools (9). The bill was stalemated in Senate-House conference and never became law. If such legislation were to be adopted, the government would have the "muscle" to stimulate widespread adoption of UMTA-recommended measures in order to attain short-term energy goals, as well as with regard to medium- and long-term air quality goals.

AUTHORITY

Both the Clean Air Act and the Urban Mass Transportation Act provide financial incentives to state and local governments to formulate a plan conforming to standards or criteria set by the federal agency. In EPA's case, this plan is the implementation plan for attaining federal air quality standards; in UMTA's case, it is a regional or areawide transportation plan. But the authority given to UMTA is far less than that given to EPA. The Urban Mass Transportation Act simply authorizes the DOT Secretary to make grants or loans to assist states and local governments; the initiative is left to them. The Clean Air Act also authorizes such financial assistance, but it requires, as Table 78 indicates, that the Administrator specify air quality goals; that the states submit plans to attain these goals within specified periods of time; and that the Administrator promulgate by regulation an implementation plan for any state or region which fails to do so to the Administration's satisfaction.

EPA Authority

In order to carry out its assignments, the EPA is given strong regulatory powers. Title III of the Clean Air Act enables the Administrator to issue any regulations necessary to carry out his function. Under this authority, detailed instructions have been issued for the preparation, approval, and promulgation of state implementation plans required by Title I, "Air Pollution Prevention and Control." These instructions include requirements for:

- Public hearings
- Implementation plan submission and revision
- Quarterly and semiannual reports on air quality data and enforcement orders
- Control strategies for individual pollutants
- Schedules of compliance
- Prevention of emergency episodes
- The state's legal authority to carry out plan
- Attaining and maintaining national air quality standards
- Identifying potential trouble spots
- Air quality surveillance
- Intergovernmental cooperation
- Requests for extensions

Where appropriate, time limits are set for meeting the stated requirements. The regulations also include extensive technical appendices with examples of attainable emission limitations and regulations. Besides providing for citizen and industry participation through hearings and applications for waiver and suspension, the Act also provides for judicial review of determinations made by the Administrator.

Regulations have also been issued to carry out Title II of the Act, which deals with vehicle emissions and fuel additives. The legislation itself, which is very explicit and detailed, prohibits the sale of a new car unless it is certified by EPA to comply with agency-set emission standards. It gives the Administrator the authority to order recall of motor vehicles if testing determines that large numbers of vehicles do not meet the standards. Tampering with control devices is also prohibited. The agency may obtain court injunctions to restrain violators and may seek civil penalties for up to $10,000 for each violation. The Administrator is given the power to set standards and certify new engine types, and he may regulate fuel and fuel additives which endanger the public health or interfere with antipollution devices.

The regulations issued to carry out this legislation cover in detail the EPA's policy on fuels and fuel additives and their registration, on procedures for certification of low-emission vehicles, and on the control of air pollution from new motor vehicles and new motor vehicle engines.

EPA's R&D function is also more stringently defined than UMTA's. Not only is the EPA Administrator authorized to conduct R&D, but the components of the R&D program are specified in the legislation, and the Administrator is directed to issue to the states and local air pollution control agencies information on air pollution techniques, including data on costs, available technology, methods of prevention and control, alternative fuels, processes and operating methods. For air pollutants not covered prior to the 1970 Act, this is to be done simultaneously with the issuance of the air quality criteria for the pollutant, i.e., 12 months after the addition of a pollutant to the EPA list.

EPA Enforcement

Because EPA's statutory authority under the Clean Air Act is very strong and its responsibilities very broad, it has been involved in a great deal of litigation. EPA's legal staff has had to handle over 90 lawsuits brought against it during its first two years by both environmental groups and private auto, utility, and chemical industries. Many of these cases have raised significant substantive and legal issues; only about 20 have been resolved (10, p. 10).

Two key cases have involved the EPA's right to grant extensions to states in the submission of their implementation plans, and its responsibility to propose and promulgate state plans or portions thereof if the state fails to do so. In the case of National Resources Defense Council Inc., et al. v. EPA (475 F 2nd 968, 1973), the court required EPA to rescind the two-year extensions of time (from 1975 to 1977) granted to states for submission of transportation and/or land-use control plans and implementation of accepted plans. In the second case, a U.S. District Court ordered the Administrator to propose regulations to complete the California implementation plan (City of Riverside et al. v. Ruckelshaus, C. D. California, 72-2122-IH). Both of these decisions were handed down in January 1973.

Despite the importance and the publicity generated by the court cases, most enforcement is administrative. EPA has direct enforcement powers through its authority to notify individual polluters that they are in violation of the law and to issue an order to stop the pollution before seeking an abatement action in court. If a violation occurs due to state inaction, EPA may notify the state and enforce abatement itself.

State and Local Responsibility for Air Pollution Control

The principle expressed in the Clean Air Act is that the prevention and control of air pollution at its source is the primary responsibility of states and local governments. However, if a state failed to exercise its prerogative to adopt standards or an implementation plan to obtain them, or if its standards or plan were found inadequate by the EPA, the federal agency may promulgate the required regulations.

An exception to this concept of placing primary responsibility on state and local governments was made with respect to automobiles. Because of the impracticability of compelling car manufacturers to comply with 50 different state laws on automotive emissions, Congress preempted the field by authorizing the federal government to establish national standards for emissions from new motor vehicles. An exception to this exception was carved out for California. Because of its longer experience with smog problems and because of its earlier laws and regulations applicable to auto emissions, it was given an exemption from the preemption provision which permits it to enforce its own stricter standards (11, pp. 596-7).

In summary, the federal government has the power to set both national emission and air quality standards. A state may set its own air quality standards as long as they are no less stringent than the federal standards (Sec. 116), but no state may set vehicle emission standards unless it had already adopted emission standards before March 1966 (Sec. 209(a)). In practice, this proviso applies only to California.

The federal government's responsibilities are compared with state responsibilities as specified in the Clean Air Act in Table 80. The further division of responsibilities between state and local districts in the state of California is summarized in Table 81. Since California's vehicle emission and air quality programs predate those of other states, the three states besides California in which the four cities described in Section 3 of this volume are located (Washington, Pennsylvania, Maryland) have not gotten as far in passing the necessary legislation for comprehensive state programs. State agency involvement and legal authority are summarized for the four states in Table 82, which is based on the cities' proposed transportation control strategies (14-17).

EPA regulations for the approval and promulgation of implementation plans require that the state have adequate personnel, funding, and authority to carry out the implementation plan, and authority to provide adequate emergency powers and to provide "to the extent necessary and practicable" for periodic inspection and testing of motor vehicle emissions. An analysis of this last requirement has indicated that states which can meet the air quality standards without regard to whether in-use vehicles remain in compliance with the national emission standards will not have to establish procedures for testing or inspection (18, Appendix I-I).

Table 82 shows that legislation and legal authority are a problem primarily with respect to mandatory auto inspection and maintenance programs, including provisions for retrofit, and gaseous conversion. Seattle seems to be ahead on gaseous conversion, since there is a Washington state law which provides fuel tax relief for conversion; California is ahead with regard to retrofit; Pennsylvania is ahead with regard to auto inspection, but its legislation applies only to 1970 and later model years and does not cover retrofit. Maryland's inspection law is safety-oriented and applies only to used cars at time of sale. Legal authority does not seem to be an issue with regard to strategies to control parking and traffic or to encourage more transit use, carpooling, and staggered work hours. Baltimore is the only city of the four which even mentions the possibility of accomplishing staggering of work hours by formally adopting

[Text continues on p. 181]

Table 80. Summary of federal and state responsibilities under the Clean Air Act.

Federal	State
TITLE I: AIR POLLUTION PREVENTION AND CONTROL	
Direct	
1. Shall encourage intergovernmental cooperation and uniform laws [102].*	1. Shall have primary responsibility for assuring air quality within the state by submitting implementation plan specifying how the national standards will be achieved and maintained [107].
2. Shall establish R&D program to study health and welfare effects of air pollutants and develop new preventive methods [103, 104].	
3. Shall issue air quality criteria and control techniques, including data on costs and available technology [108].	2. Shall submit implementation plan providing for implementation, maintenance and enforcement of national air quality standards [110].
4. Shall promulgate national ambient air quality standards [109].	
5. Shall approve or disapprove state implementation plans and extend the deadline for such plans.	
6. Shall notify violators of state implementation plans, issue orders of compliance, or bring civil action.	
7. May require records, reports and the installation of monitoring equipment and testing procedures. May delegate this authority to the state if proposed state procedure is deemed adequate [114].	3. May require records, reports, and the installation of monitoring equipment and testing procedures if delegated the authority by the federal government [114].
Indirect	
8. Shall propose a state implementation plan if state fails to do so within time prescribed or fails to revise a rejected plan, and promulgate this plan by regulation within 6 months unless state adopts a satisfactory revised plan [110].	
9. Shall notify a state of widespread violations of an implementation plan. May assume enforcement of plan by issuing orders and bringing civil action until the state can enforce the plan itself.	

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*Brackets enclose applicable section numbers in the Act.

Table 80 (continued)

Federal	State
TITLE II: EMISSION STANDARDS FOR MOVING SOURCES, PART A: MOTOR VEHICLE EMISSION AND FUEL STANDARDS	
1. Shall prescribe motor vehicle emission standards [202].	1. May adopt and enforce vehicle emission standards, but only if the state has adopted emission control standards before March 1966 and the Administrator rules that these standards are consistent with the requirements of the Act and that there is no reason for them to be more stringent than the federal standards.
2. Shall test and certify new motor vehicles, motor vehicle engines, and emission control systems for motor vehicles [206]. Without such a certification, sale of such vehicles or systems is illegal [202].	
3. Shall require auto manufacturers to warrantee the emission control device of new vehicles for the length of the vehicle's useful life [207].	
4. Shall designate fuels and fuel additives to be registered and register them prior to lawful sale [211].	2. May prescribe and enforce fuel and fuel additive controls as long as the Administrator has approved the measures in an implementation plan [211].
5. Certify low-emission vehicles for procurement by the U.S. government [212].	

NOTE: Sections of the Act concerned with stationary source and aircraft emissions are not included. For explanation, see note to Table 78, p. 167.

SOURCE: Reference 2.

Table 81. Division of air quality responsibilities between state and local districts in California.

State Air Resources Board	Local air pollution control districts and basinwide coordinating councils (2 or more districts in air basin)
Direct	
1. Carry out motor vehicle emission control program, including establishing standards and test procedures for new and used vehicles, and certifying and enforcing use of retrofit control devices.	1. Formulate basinwide implementation plans (councils).
2. Coordinate statewide control efforts and supervise local district efforts.	2. Enforce basinwide implementation plans (local districts.) Includes authority to regulate additives in gasoline and to establish a permit system.
3. Promulgate statewide air quality standards.	
4. Operate air quality monitoring network in cooperation with districts. Publish data.	3. Operate air quality monitoring network in cooperation with the state.
5. Conduct applied research to solve state air pollution problems.	4. Develop basic land use plan, regulate traffic, promote public transit (county planning agency).
6. Advise and assist local districts. Review and revise basinwide implementation plans and local rules and regulations.	5. Approve and implement land use plan, including making zoning consistent with general plan (city council or county board of supervisors).
Indirect	
7. May establish basinwide air pollution control plans if district-submitted plans are judged inadequate. May exercise all powers held by local districts to achieve air quality standards, including adoption of rules and regulations.	

NOTE: Legislation has been requested to establish authority for mandatory vehicle inspection for emission control; to require city and county general plans to include an air quality element and permit state review; to permit the ARB to regulate emissions from new and used motorcycles, off-road vehicles, and diesel construction equipment.

SOURCE: References 12 and 13.

Table 82. State and local agencies with authority to carry out proposed transportation control strategies: Los Angeles, Philadelphia, Seattle, Baltimore.

City and pollutants for which strategy required	Control Strategy Description							
	Improve transit	Retrofit, Inspec. & Maintenance	Gaseous Conver.	Parking(1)	Carpools & Staggered Hours	Others		
						Gas Rationing	Evaporation Controls	
							Vehicle	Industry
Los Angeles (CO, HC, NO_x)	SCRTD SCAG OCTD	ARB; further legislation (2) reqd.	Legislation required	—	—	Legislation required	Legislation required	Local APCD
						Traffic restraints		Zoning
Philadelphia (CO)	SEPTA	Legislation required; revise existing law (3).	—	City council, PennDOT	—	City council, PennDOT		City council
						PRT	Traffic Signals	Exclude or Restrict Older Vehicles
Seattle (CO, HC)	METRO	New legislation required (4)	Extend state fuel tax relief beyond 1975.	No legal authority required for these strategies.		Local legislation required to designate agency.	City	Legislation required

Table 82 (continued)

City and pollutants for which strategy required	Control Strategy Description					
	Improve transit	Retrofit, Inspec. & Maintenance	Gaseous Conver.	Parking	Carpools & Staggered Hours	Others
						Traffic Flow Improvement
Baltimore (CO, HC)	MTS City	MVA, State Police; Proposed bill not enacted (5).	—	Parking commission cannot regulate rates. City could raise tax.	Legal authority required if city wants to make official policy.	City

NOTES:

1. Proposed parking strategies vary considerably from city to city. Philadelphia's would involve regulation and a tax, and Baltimore's increasing the charges, whereas Seattle envisions only the preparation of a guide on how to find a parking space faster to decrease cruising time.
2. Legislation enacted in 1971 requires the California Air Resources Board to set up a schedule for the installation of an effective emission control device in 1955-1970 model cars and light duty trucks. The law is enforced by requiring a certificate of compliance for reregistration and change of ownership beginning in 1973. Legislation calling for mandatory inspection and maintenance of all in-use vehicles in the South Coast Air Basin was enacted in January 1974.
3. Pennsylvania law is geared only to enforcing Clean Air Act provisions regarding vehicles manufactured after February 1971. Specifically, the law sets a fine for tampering with new car engines, and gives the state the authority to license private firms to carry out motor vehicle inspection. The law would have to be changed to require or permit retrofitting.
4. Washington State has no vehicle inspection law at all and does not meet federal traffic safety standards for this reason. New legislation would be required for an inspection program or to provide for fuel tax relief for retrofitting of in-use vehicles.

Table 82 (continued)

5. Existing Maryland legislation requires safety inspection of used cars at time of sale. A bill to provide periodic motor vehicle inspections, including emission testing and optional diagnostic tests for passenger cars and trucks failed to pass during the 1972 legislative session. It was reintroduced to the 1973 session [but will probably not pass]. An earlier system of inspections conducted by private garages was not well controlled and was written out by law in 1965.

SOURCES: Individual city transportation control plans (14-17).

a municipal policy. None of the cities mentions any legal issues arising from promoting transit use.

For the moment, EPA seems to be less concerned with legal authority than with getting an approved implementation plan, including transportation control strategies, for each state and its metro regions. In the Code of Federal Regulations, where EPA's approval and promulgation of state implementation plans are recorded, two of the four states we are concerned with are indicated specifically not to have adequate legal authority: Maryland, for carrying out its implementation plan, and California, for emergency action and provision of information to the public. The applicable section is not mentioned in the relevant subparts for Washington or Pennsylvania (4, volume on *Federal Regulations*).

Apparently the EPA feels confident that once plans are approved, its own legal authority will be adequate for enforcement of any part of a state's implementation plan, although it would prefer that the states and local agencies handle enforcement. As the *Federal Register* for Nov. 6, 1973 states (19, p. 30633):

> "Although the legal authority to enforce these plans [transportation control plans] is clear, the primary effort—as is true for all implementation plans—will be directed toward working with the States both to develop and to implement effective strategies. This effort should continue even after these measures have been promulgated, so that all affected States eventually assume voluntarily the direct responsibility for enforcement of the plans.
>
> "In some instances, new regulations will be necessary on a State level. In others, existing regulations will be adequate. Where State-enacted statutory authority is not adequate, the Clean Air Act and these regulations can provide the legal basis for programs at the State or local level."

UMTA Authority

In contrast to EPA, UMTA's authority is exercised solely through the approval of local grants and loans for facilities and equipment (capital grants), for technical studies, managerial training, and research and training. In fact, UMTA is expressly forbidden to interfere in the operation of any transit system by Section 12(e) of the Urban Mass Transportation Act, which reads as follows (1):

> "None of the provisions of this Act shall be construed to authorize the Secretary to regulate in any manner the mode of operation of any mass transportation system with respect to which a grant is made . . . or, after such grant is made, to regulate the rates, fares, tolls, rentals, or other charges fixed or prescribed for such system by any local public or private transit agency; but nothing in this subsection shall prevent the Secretary from taking such actions as may be necessary to require compliance by the agency or agencies involved with any undertaking furnished by such agency or agencies in connection with the application for the grant."

The Act does make certain stipulations for the approval of capital grants, which account for the largest part of UMTA's funds, and states that other types of funding are to be made "in accordance with criteria established by the Secretary." The conditions for capital grants are summarized as follows:*

1. The applicant has legal, financial, and technical capability to carry out the proposed project (Sec. 3(a)).
2. The project contributes to a program for a unified or officially coordinated urban transportation system which meets criteria established by the Secretary (Sec. 4(a)).
3. Public hearings have been held, unless no one in the community requested them, and the project's economic, social, and environmental effects have been considered (Sec. 3(d)).
4. No adverse environmental effect is likely to result from the project (Sec. 14(c)).
5. Buses acquired must meet the standards prescribed by EPA (Federal Highway Act of 1970, Sec. 165(a); P.L. 91-605 84 Stat. 1713, 23 U.S.C. 137).
6. Projects must be planned so that elderly and handicapped persons can effectively use mass transportation facilities (same as No. 5, Sec. 165(b)).

It would seem that UMTA has some leverage through refusal to approve capital grants for imposing specific demands on local applicants. Apparently, the agency has not chosen to define such criteria in a stringent, quantitative way. UMTA's capital grants staff prepared in July 1972 a set of guidelines which attempt to define the three basic capital grant criteria (achieve land-use patterns minimizing space demands for transportation; improve passenger mobility during peak hours; provide service for the carless). According to March 1973 testimony by UMTA Administrator Herringer, the capital grant applicant works first with the technical studies staff to develop his capital grant application in line with the guidelines, but he says that there are no "hard and fast rules. There is a lot of judgment." His testimony implies that the capital grants guidelines cannot be made more specific until the relevant factors can be measured (3, p. 737):

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*Other conditions are also given in the Act; they are basically procedural rather than substantive in nature. These include requirements for equal opportunity employment, uniform relocation assistance and real property acquisition, equal wages for construction workers, and abstention from charter or school bus operations by grant applicants.

> "How do you measure mobility? It's a very difficult thing to do. Not even to speak of the first objective [land-use patterns] . . . That is a very difficult objective to measure . . .. We need better measurements of priorities . . .. We have to refine our measurements."

Thus the authority of UMTA would appear to be stronger in the legislation than in actual practice. The factors holding back a more precise definition of goals and how to reach them would appear to be both legislative and technological. The legislation does not specifically direct the UMTA Administrator to do away with congestion or some other urban transportation ill with the same force as the Clean Air Act directs the EPA Administrator to do away with unhealthy and destructive air pollution. It also seems unlikely that newer, more stringent guidelines, whether administratively or legally imposed, could be applied to the many transit systems already receiving UMTA funds. It was ruled in 1971, for example, that the public hearing and environmental protection requirements of the Act which were added in 1970 do not apply to projects for which capital grant funding was approved prior to passage of those amendments (1, p. 4).

UMTA could still impose more stiff requirements within the existing legislation if the state of the art permitted the formulation of more definite guidelines. However, to date no reliable way has been developed to measure or test favorable land-use patterns or mobility which would be comparable to the grams-per-mile EPA measure or to the detailed engine test procedures specified in EPA regulations.

Short of a more stringent approach to capital grants funding as suggested above, there is little that UMTA or DOT can do, even in an emergency situation, to quickly set up a new action program. An inhouse TSC (DOT) research paper prepared in October 1973 (20), supplemented by a careful reading of the UMTA Act, indicates that the DOT Secretary's emergency powers do not authorize him to take any emergency action except with regard to the regulation of airspace. During the recent increase in interest in alternatives to established patterns of auto travel, UMTA has moved quickly to provide information on topics of immediate applicability, such as carpooling. In this way, it is making available work already conducted in its R&D program, and is also responding to Section 102 of the National Environmental Policy Act of 1969 (P.L. 91-190, Stat. 852 USCA 4321) which directs all agencies of the federal government to "make available to states, counties, municipalities, institutions, and individuals, advice and information useful in restoring, maintaining, and enhancing the quality of the environment."

PROGRAMS

An overall review of EPA's and UMTA's major program efforts and of one of the suggested FEA strategies is presented next to set the stage for a brief evaluation at the end of this section of the impact of current and future trends (described in Sections 2 and 3) on federal goals and programs. This review also provides a perspective on what is already being done to offset these trends, which is helpful in viewing the offsetting phenomena enumerated in Volume 1.

Major EPA Programs and Accomplishments

FEDERAL PROGRAMS. EPA groups its responsibilities to the environment under six categories: air, water quality and supply, solid wastes, pesticides, radiation, and noise. In all of these areas, it carries on abatement and control activities and R&D. It has enforcement programs for air, water quality, and pesticides.

The programs of concern in this study are those dealing with air quality, which come under the aegis of the assistant administrator for air and water programs, and are carried out by the Office of Air Quality Planning and Standards and the Office of Mobile Source Air Pollution Control. Figure 41 shows these offices' place in the agency's organizational structure. Air quality pro-

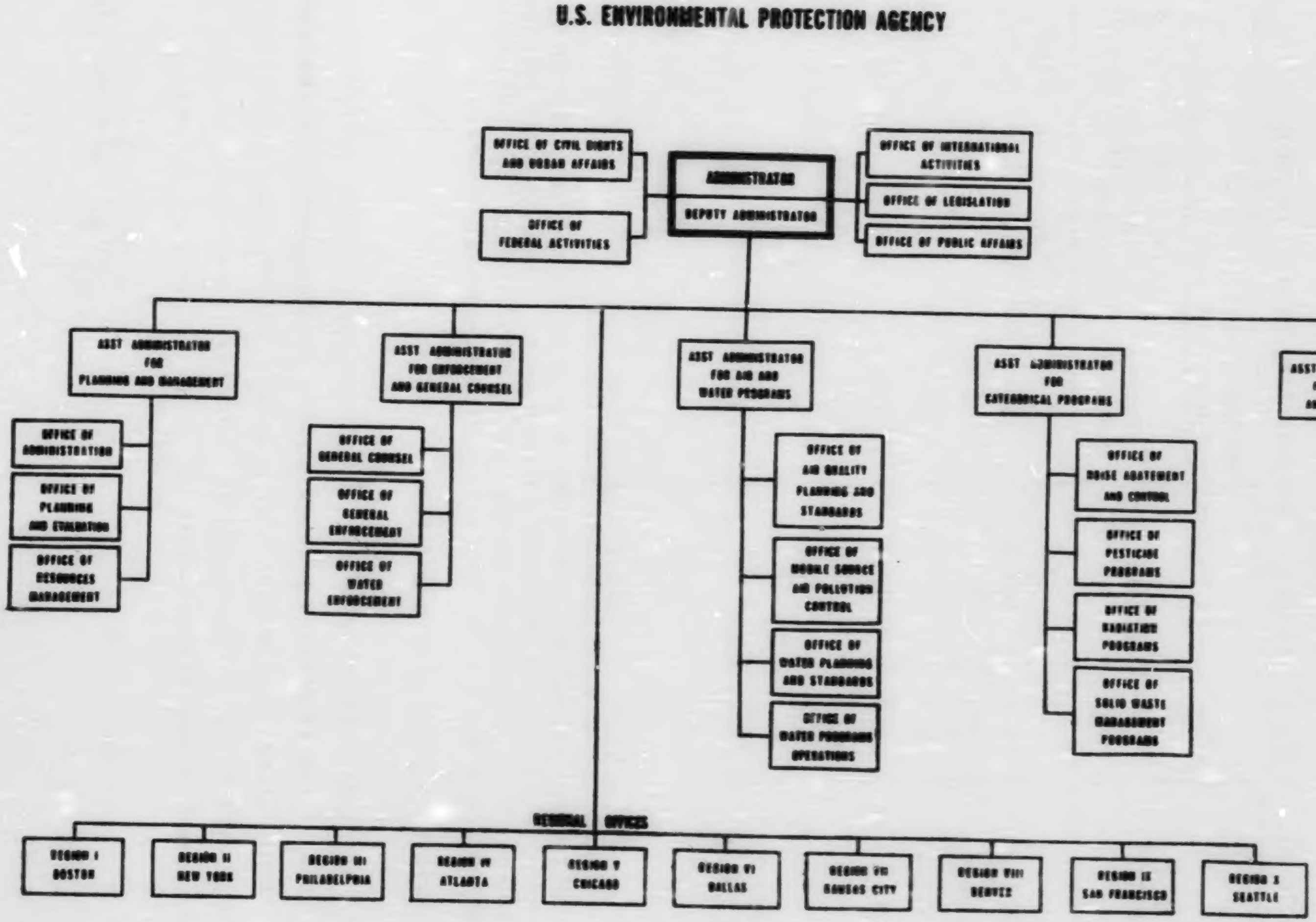
U.S. ENVIRONMENTAL PROTECTION AGENCY
OFFICE OF CIVIL RIGHTS AND URBAN AFFAIRS
OFFICE OF FEDERAL ACTIVITIES
ADMINISTRATOR
DEPUTY ADMINISTRATOR
OFFICE OF INTERNATIONAL ACTIVITIES
OFFICE OF LEGISLATION
OFFICE OF PUBLIC AFFAIRS
ASST ADMINISTRATOR FOR PLANNING AND MANAGEMENT
OFFICE OF ADMINISTRATION
OFFICE OF PLANNING AND EVALUATION
OFFICE OF RESOURCES MANAGEMENT
ASST ADMINISTRATOR FOR ENFORCEMENT AND GENERAL COUNSEL
OFFICE OF GENERAL COUNSEL
OFFICE OF GENERAL ENFORCEMENT
OFFICE OF WATER ENFORCEMENT
ASST ADMINISTRATOR FOR AIR AND WATER PROGRAMS
OFFICE OF AIR QUALITY PLANNING AND STANDARDS
OFFICE OF MOBILE SOURCE AIR POLLUTION CONTROL
OFFICE OF WATER PLANNING AND STANDARDS
OFFICE OF WATER PROGRAMS OPERATIONS
ASST ADMINISTRATOR FOR CATEGORICAL PROGRAMS
OFFICE OF NOISE ABATEMENT AND CONTROL
OFFICE OF PESTICIDE PROGRAMS
OFFICE OF RADIATION PROGRAMS
OFFICE OF SOLID WASTE MANAGEMENT PROGRAMS
ASST ADMINISTRATOR FOR RESEARCH AND MONITORING
OFFICE OF MONITORING
OFFICE OF PROGRAM OPERATIONS
OFFICE OF RESEARCH
REGIONAL OFFICES
REGION I BOSTON
REGION II NEW YORK
REGION III PHILADELPHIA
REGION IV ATLANTA
REGION V CHICAGO
REGION VI DALLAS
REGION VII KANSAS CITY
REGION VIII DENVER
REGION IX SAN FRANCISCO
REGION X SEATTLE

Figure 41. EPA organizational structure.

Source: Reference 21, p. 438.

grams, with about one-third of the total operating budget (1974), are second only to those of water quality, which account for nearly 40 percent. Table 83 shows the 1974 operating budget by program category and type of activity. As the table shows, about 60 percent of air funds go into abatement, control, and enforcement, and the rest to R&D.

Table 83. Major EPA programs and operating budget, FY 1974.

PROGRAM CATEGORIES	PROGRAM ACTIVITIES (FY available funds, millions of dollars)				
	R&D	Abatement & Control	Enforcement	Scientific Activities Overseas	Total
Air	57.1	79.7	8.7	0.8	146.3
Water Quality	46.7	101.9	24.4	1.3	174.3
Water Supply	2.3	2.0	—	—	4.3
Solid Wastes	2.2	3.6	—	0.2	6.0
Pesticides	5.4	17.2	3.1	0.4	26.1
Radiation	2.4	4.6	—	0.4	7.4
Noise	0.6	3.5	—	0.2	4.3
Interdisciplinary	14.3	—	—	0.6	14.9
Program Management	17.3	31.5	11.2	0.1	60.1
Total	128.3	244.1	47.4	4.0	443.7*

*Total agency budget is $3,994.6 million, including extra-operating funds of $50.8 million for agency and regional management, $3,400 million in contract authority for construction grants, $96 million in contract authority for management, and $4 million for facilities not shown elsewhere.

SOURCE: Reference 21, pp. 449a and 449b.

EPA's transportation-related air quality accomplishments can best be seen in light of the strategy expressed a year ago (March 1973) by the then Administrator, William Ruckleshaus (21, p. 450). The programs emphasized in the strategy were the correct setting of standards, support of state and local air control agency efforts—both abatement and control activities—

and enforcement. These three areas have received greater funds in 1974, although the total for air programs has decreased. Enforcement activities in particular are becoming increasingly important as EPA moves out of its first three formative years to focus on the implementation of the legislation. Enforcement expenditures have increased from 3 to 10 percent of the total since 1971, and the enforcement program stepped up its efforts nearly tenfold from 1973 to 1974 in terms of number of inquiries handled. It was anticipating 2,000 inquiries regarding violations of standards and regulations in 1974 vs 300 in 1973; six public hearings on extension and waiver requests vs five in 1973; six recalls of in-use vehicles (same as 1973); and the initiation of 70 civil actions to obtain compliance with EPA regulations vs 8 in 1973.

As important as enforcement is to EPA's attainment of its goals, the bulk of its results will come from voluntary state and local cooperation with the activities of its two key abatement and control divisions, Air Mobile Sources ($9.8 million) and Air Technical Assistance ($10 million). The former division sets vehicle emission standards, promulgates regulations, monitors prototype and sample production vehicles from the auto manufacturers, while the latter reviews and approves or promulgates state implementation plans, including transportation control plans, and provides technical assistance and training. It has completed review of all the state plans for achieving the primary AQS and nearly all for secondary standards, and should complete review of municipal transportation control plans by the end of fiscal 1974.

The largest dollar component of abatement and control is that of the state control agency support division, which disbursed $50 million in 1973 ($51 in 1974) to aid states and localities in preparing their implementation plans and planning their execution.

It is at the state level that EPA-required programs come closest to actions also sponsored by UMTA. The one area of common interest at the national level is in EPA's mobile source control technology program, part of its R&D effort, whcih in 1973 tested preprototype Rankine cycle systems, completed a gas turbine engine demonstration which meets the 1976 emission control levels, and received stratified charge engines for test and demonstration. This group plans to complete in 1974 a comprehensive report assessing the status and prospects for alternative systems for auto propulsion. UMTA is also involved in propulsion R&D, as will be described below. But most of the transportation-related EPA supported programs may be found in the various transportation control plans required of 29 metropolitan regions in order to reduce vehicle emissions to meet the 1975 or 1977 standards, after considering the reductions provided for by stationary source control and the federal motor vehicle emission controls.

METROPOLITAN TRANSPORTATION CONTROL PLANS.* The application of stringent stationary source controls and the federal new car emissions standards should reduce the number of Air Quality Control Regions (AQCRs) projected to exceed the ambient air quality standards in 1975 to about 29. EPA is in the process of finalizing and approving in-use vehicle control plans for these 29 regions. Of these 29 regions, it is expected that El Paso, Rochester and Cincinnati can achieve the standards by 1975 through the implementation of a vehicle inspection and maintenance program and improvements in existing transit systems. However, these three regions are projected to achieve the air quality standards by 1977 through the influx of new vehicles alone. An additional seven regions, including Springfield, Seattle, Spokane, Dallas, Minneapolis-St. Paul, Chicago and Portland, are projected to meet the air quality standards by 1975 through the use of an inspection and maintenance system and substantial improvements in transit.

The remaining 19 regions all require hardware retrofits, an inspection and maintenance system, and/or significant reductions in vehicle usage to achieve the standards by 1975. However, lead time constraints on the implementation of major traffic controls and transit improvements, and on the installation of various emissions hardware controls, have pushed the date of air quality standard attainment beyond 1975 for these regions. Only six of the 19, including Philadelphia, Pittsburgh, Washington, D.C., Salt Lake City, San Antonio and New York City (CO only)**, can achieve the air quality standards by 1977 only with the use of emissions control retrofits as well as major transit improvements and other measures to substantially reduce vehicle use by up to 20 percent. Based on EPA's present analysis, the remaining 14 regions of Phoenix, Baltimore, Boston, Denver, New York City, San Joaquin, San Diego, Southeast Desert, Sacramento, Los Angeles, San Francisco, Houston, Beaumont, and Fairbanks probably cannot be reasonably expected to meet the air quality standards even by 1977.

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*The following discussion of the status of transportation control plans in major urban areas draws heavily on Reference 22, pp. 29-36.

**The downtown New York City CO problem should be cleaned up in 1977, but the areawide oxidant problem, involving portions of New York, New Jersey and Connecticut, will require reductions in emissions areawide which are beyond present expectations for 1977.

Final determination of both the exact reductions in traffic required and the feasibility of achieving those reductions cannot be made until information presented during public hearings on the individual plans has been analyzed to determine exactly what each of the regions can do in terms of transit improvement and traffic reduction by 1977. Furthermore, because many of the AQCRs have projected air quality levels very near the standards in 1977, slight errors in the assumptions used to predict the air quality can greatly affect the EPA count of those regions which will or will not comply with the standards. Table 84 shows the impact of overestimating or underestimating two of the most critical variables: baseline air quality and base-year contribution of stationary sources. The data show that if errors were consistently made in one direction or the other, a difference of

Table 84. Impact of analytical uncertainties on number of AQCRs which will comply with EPA oxidant and CO standards by 1977.

Impact of Uncertainties	Do Not Comply in 1977*	Comply in 1977
Regions requiring in-use vehicle controls in order to comply with oxidant and CO standards:		
Base Case	14	15
Favorable**	10	19
Unfavorable***	25	4

*Assuming VMT reduction over 20 percent is not feasible.
**Baseline air quality and stationary source contribution overestimated; growth rate and control effectiveness assumed correct.
***Baseline air quality and stationary source contribution underestimated; growth rate and control effectiveness assumed correct.
Source: Reference 22, p. 36.

15 regions in or out of compliance could result. It also indicates that EPA's estimate of only 14 regions not being in compliance by 1977 is probably optimistic.

This high degree of sensitivity and uncertainty further suggests that the ability of EPA or anyone else to make a firm commitment on exactly which regions will or will not comply by a given date is somewhat limited unless, of course, one applies a very large margin of safety to the allowable emissions ceiling.

As Table 82 shows (pp. 178-9), all four of the cities addressed in this report include in their transportation control plans transit improvements and vehicle retrofit, inspection and maintenance strategies, and three of the four also included some form of parking controls. Two cities include carpooling and staggered work hours, and individual cities include as strategies gas rationing and evaporative controls (Los Angeles), traffic restraints and zoning (Philadelphia), PRT, traffic signal system, restriction or exclusion of older vehicles (Seattle), and traffic flow improvements (Baltimore).

Figure 42 and Tables 85 through 88 show in greater detail both the types of transportation control strategies proposed by the four cities and their expected impacts on emissions. The listing of control strategies for Los Angeles in Table 85 also illustrates that the final strategies are arrived at through an iterative process involving EPA, the state, and localities. The Los Angeles plan, promulgated by EPA in November 1973 (23, pp. 31232-31255), has been accepted by the state and localities with the exception of the parking surcharge measure (24).*

In promulgating the plan, the EPA also granted an extension of the deadline for achieving the standards to 1977 "because the necessary technology or other alternatives would not be available." It further stated that "even if all the reasonable measures mentioned above are imposed on the timetable indicated, it is estimated that the national standards for photochemical oxidants will not be met in the region by 1977 . . .. However, the Agency will utilize every means available to avoid the need to impose severe gasoline rationing to reach that goal by 1977." No need for legislation to carry out the gasoline limitations is specified. The applicable regulation states only that if the Adminis-

[Text continues on p. 196]

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*All EPA parking surcharge regulations were permanently withdrawn in January 1974. See discussion in Volume 1 of this report, pp. 3-36 and 3-37.

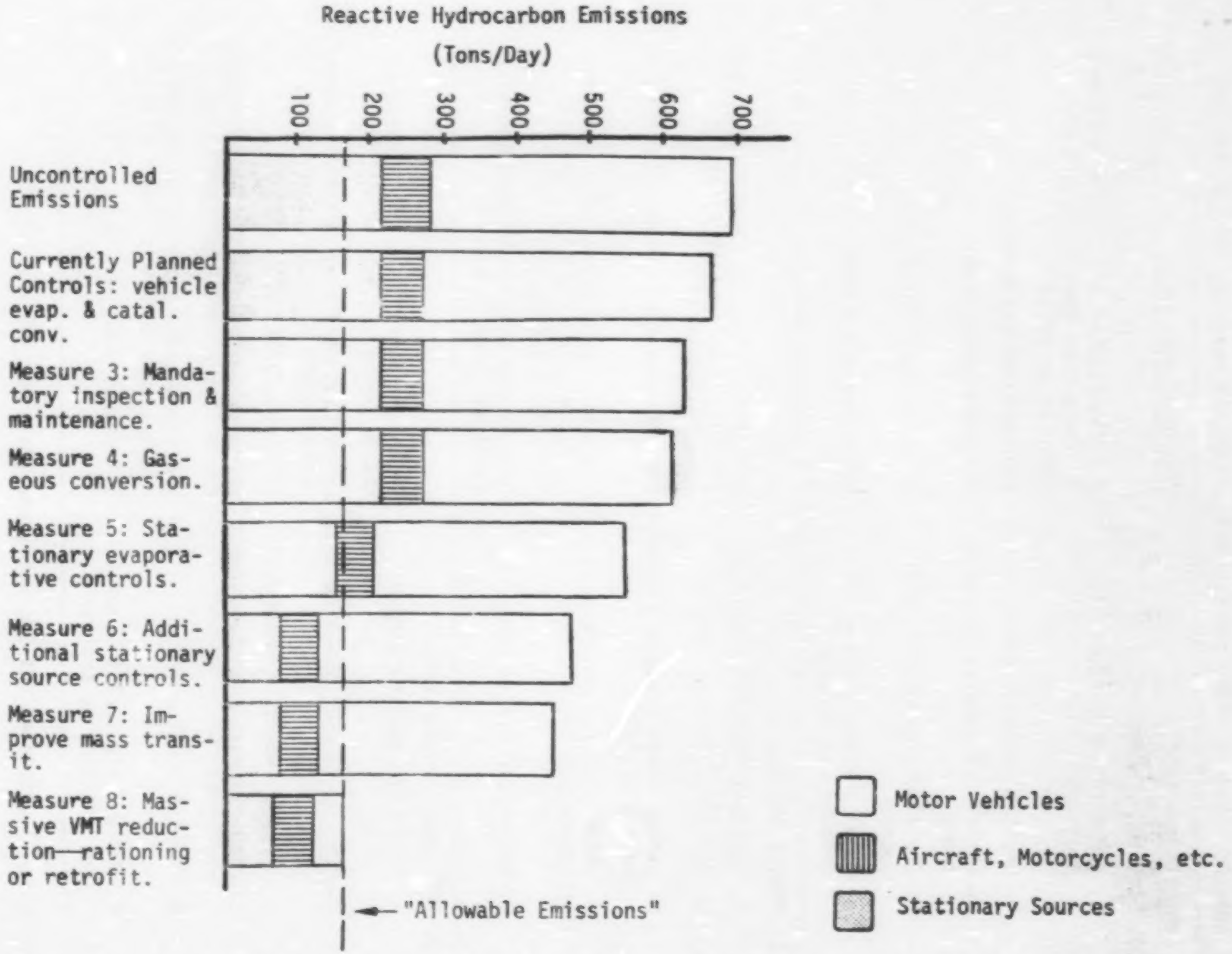


Figure 42. The impact of state-proposed transportation control strategy on reducing reactive hydrocarbon emissions in Los Angeles by 1977.

SOURCE: Reference 14, p. 194.

Table 85. EPA-approved transportation control measures for Los Angeles.

Control measures*	Origin of measure
1. Stationary sources	
a. Vapor recovery at service stations	EPA-promulgated plan. Also included in state-submitted plan, not yet formally approved.
b. Organic solvents usage	EPA-approved state plan.
c. Control of degreasing operations	EPA-promulgated plan.
d. Dry cleaning solvent vapor losses	EPA-promulgated plan.
e. Metal surface coating thinner and reducer	EPA-promulgated plan.
2. Mobile sources	
a. Catalyst retrofit ('66-'74), LDV and MDV	EPA-promulgated plan. Also included in state-submitted plan, not yet formally approved.
b. Vacuum spark advance disconnect ('55-'65)	EPA-approved state plan.
c. Inspection and maintenance (loaded)	EPA-promulgated plan. Also included in state-submitted plan, not yet formally approved.
d. Motorcycle limitations	Only if new motorcycle emission standards not promulgated.
3. VMT reduction measures	
a. Exclusive bus and carpool lanes	EPA-promulgated plan. Also recommended by state and local task force.
b. Bus and carpool matching	EPA-promulgated plan. Also recommended by state and local task force.
c. Parking supply management	EPA-promulgated plan only.
d. Mass transit incentives for employees	EPA-promulgated plan. Also recommended by state and local task force.
e. Parking surcharge	EPA-promulgated plan. Also recommended by state and local task force.
f. VMT and air quality improvement monitoring program	EPA-promulgated plan only.

*Gasoline limitations not included; see text, pp. 190 and 196.

SOURCE: Reference 23, p. 31233.

Table 86. Impact of EPA-approved transportation control strategies for Philadelphia by May 1976.

	Carbon monoxide		Hydrocarbons	
	Tons per year	Percent of base year emissions	Tons per year	Percent of base year emissions
SOURCE CATEGORY				
1971 Tons per year (base year)	28,805	100.0	218,159	100.0
Reduction required to reach NAAQS	15,987	55.5	118,417	54.3
STATIONARY SOURCES				
Emissions without control strategy	(2)	0	105,208	48.2
Expected reductions from existing regulations:				
Solvent control	0		7,803	3.6
Gasoline handling vapor recovery: Bulk terminals [1]	0		3,420	1.6
Aircraft ground operations	0		416	.2
Other stationary source rule strengthening	0		11,775	5.4
Stationary source emissions remaining	(2)	0	81,794	37.4
MOBILE SOURCES				
Emissions from LDV's and HDV's with control strategy	28,805	100.0	112,951	51.8
Expected reductions:				
Federal motor vehicle control program [1]	12,664	44.0	49,528	22.7
Inspection and maintenance (LDV and HDV)	1,206	4.2	4,244	1.9
Air bleed retrofit of pre-1968 cars	1,386	4.8	1,555	.7
*VMT measures	682	2.4	477	.32
Traffic flow improvements	139	.5		
Mobile source emissions remaining	12,728	44.1	57,147	26.2
Total reductions	16,077	55.8	79,218	36.3
Total emissions remaining	12,728	44.2	138,941	63.7
Total allowable emissions	12,815	44.5	99,742	45.7

[1] Includes effect of VMT reductions.
[2] Negligible.

*Key to VMT measures:

Proposed	Promulgated
Mass transit improvements	Mass transit improvements.
Exclusive bus/carpool lanes	Exclusive bus/carpool lanes.
Parking restrictions	Parking restrictions.
Traffic flow improvements	Traffic flow improvements.
20 percent vehicle exclusion	Management of parking supply.
Gasoline distribution limitation	Carpool locator program.
	Employer parking policy.
	Bikeway network.

Source: Reference 25, p. 32887.

Table 87. State-recommended transportation control strategies for Seattle CBD and their effects.

	1977 Allowable	Without Strategies				With Strategies (1977)				
		1971	1977	1978	1979	(1)	+ (2)	+ (3)	+ (4)	+ (5)
a. HC Emission Densities (kg/8 hr/mi^2)										
Vehicular	6,275	14,301	8,175*	6,951	6,001	8,032	7,875	7,579	6,275	3,830
Non-vehicular	292	292	292	292	292	292	292	292	292	292
TOTAL	6,567	14,593	8,467	7,243	6,293	8,324	8,167	7,871	6,567	4,122
b. Air Quality (8-hr average CO concentration in ppm)	9.0									
Observed (2nd highest)		20								
Estimated			11.6	9.9	8.6	11.4	11.2	10.8	9.0	5.6

Key to Strategies:
(1) METRO Transit Development.
(2) Fringe Parking and PRT.
(3) Improved Signal System.
(4) Exclusion of pre-controlled vehicles.
(5) Retrofit.

Example calculation based on: (1) "air bleed to intake manifold" on pre-1968 models, and (2) "oxidizing catalytic converter with distributor vacuum advance disconnect" on 1968-1974 models.

*Represents reduction in vehicular emissions from 1971 levels of:

	Percent
From federal motor vehicle control program:	43
Additional reduction from 1971 level required by transportation control strategies:	13
Reduction from 1977 "no stragegy" level required by Transportation Control Strategies:	23

SOURCE: Reference 16, pp. I-8 and IV-3.

Table 88. State-recommended air quality control strategies for Baltimore and their estimated effects.

		Hydrocarbon Emissions (kg/day) (based on 6-9 a.m. peak emissions)		Carbon Monoxide-Central Area ($kg/mi^2/day$) Emission Density	
1977 Expected		30,360		4,868	
Maximum allowable		18,244		3,078	
Further reduction required		12,116		1,790	
Control Action	Effect		Subtotal		Subtotal
Traffic flow improvements to increase speed	Emissions decrease equivalent to 10% VMT reduction	-2,162	9,954	- 467	1,323
Total subsidy of transit fares with associated service improvements and parking restraints	15% decrease in VMT	-3,243	6,711	- 700	623
Inspection and maintenance program	Effective emission reduction: HC-4.01% and CO-3.19%*	- 650	6,061	- 112	511
Control Device Retrofit: a. Catalytic converters on pre-1975 light-duty vehicles	Effective emission reduction: HC-23.33% and CO-27.33%	-3,783	2,278	- 957	0
b. Evaporative and crankcase control on pre-1973 heavy-duty gasoline vehicles	Reduction of hydrocarbon emissions by 6.8% of heavy-duty vehicle contribution	-2,612	0	- - - No CO Effect - - -	

*In both cases, percent reductions apply to the 75% of motor vehicle emissions remaining after VMT reductions.

SOURCE: Reference 17, p. I-13.

trator determines that air quality standards for CO and photochemical oxidants will not be met by May 1977, "the Administrator shall implement a program," which would limit the amount of gasoline delivered to retail outlets to the amount which, when combusted, would result in the attainment of the standards.

Los Angeles was the first of 17 cities, including Baltimore, for which EPA expected to propose transportation control strategies in order to correct deficiencies in the state-submitted proposals or because no plan was submitted. The Baltimore plan was deemed inadequate due to the lack of specific vehicle-miles-traveled (VMT) reduction measures and the inadequate data support for emission reductions to result from inspection and maintenance programs, and due to the lack of an adequately detailed description of the latter program. The Philadelphia and Seattle transportation control plans were generally approved, aside from procedural deficiencies (26, p. 16554).

It appears in summary that Seattle can meet the required standards by 1975; Philadelphia can meet the CO standard by 1976 and the HC standard by 1977; in the Los Angeles region, CO levels should be attained between 1980 and 1985 but meeting the NO_2 requirement will take longer, and the HC standard is unattainable by 1977 without gas rationing or a massive retrofit program; and the Baltimore region cannot reasonably be expected to meet the air quality standards until after 1977.

Implementation of the approved transportation control strategies should get underway by mid-1974, since EPA plans to complete its review and promulgation activities by then, and since all four states involved must by July 1974 have passed legislation giving them adequate power to carry out their strategies; California must have an inspection and maintenance law by June 1974 and a retrofit law by September (4, Federal Regulations, "Approval of Plans").

Major UMTA Programs and Accomplishments

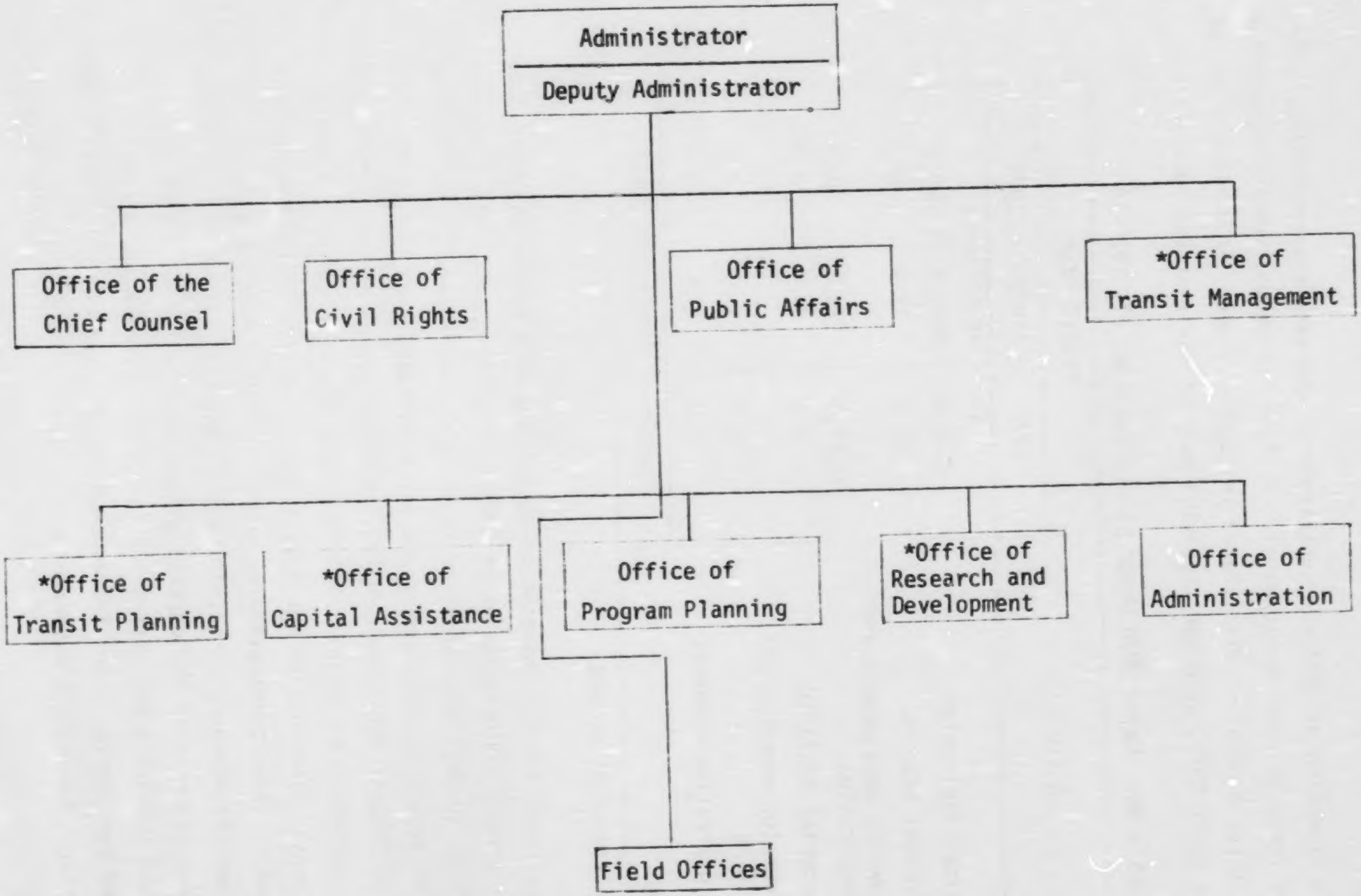
UMTA's programs may be divided into three groups: those which disburse funds to directly aid mass transit systems (capital grants and loans); those which disburse funds to aid transportation planning and training (technical studies and managerial and university research and training); and those which define the future direction of UMTA and contribute to the mass transportation state of the art (research and development). As Table 89 shows, roughly 90 percent of UMTA's total funding is distributed as capital grants ($872 million out of $1 billion in FY 1974, with R&D receiving most of the rest ($80 million).

Table 89. Major UMTA programs and budgets, FYs 1972-74.

Activity	Fiscal Year		
	1972	1973	1974
	(million dollars)		
Capital facilities	$510.0	$863.7	$ 872.0
Technical studies	25.0	33.5	38.0
Research, development and demonstration	61.4	73.3	80.0
Managerial training	0.5	0.5	0.5
University research and training	2.5	2.5	2.5
Administrative expenses	4.6	6.5	7.0
TOTAL	$604.0	$980.0	$1,000.0

SOURCE: Reference 3, p. 668.

The available funding information on which this division is based does not reflect a major reorganization of UMTA in September 1973, which created two new offices to deal with specific topics previously part of the work of the Office of Research, Development and Demonstrations (see Figure 43). The new Office of Transit Management deals with transit management projects previously part of RD&D and administers managerial training grants. The new Office of Transit Planning has taken over administration of UMTA demonstrations, including transit integration, and of technical studies grants, and also evaluates the adequacy of local transit planning. The Office of Capital Assistance administers the capital grants program for acquiring, constructing, and improving facilities and equipment for mass transportation services, and the capital loans for advance acquisition of real property for use in planning urban mass transportation systems.


Administrator
Deputy Administrator
Office of the Chief Counsel
Office of Civil Rights
Office of Public Affairs
*Office of Transit Management
*Office of Transit Planning
*Office of Capital Assistance
Office of Program Planning
*Office of Research and Development
Office of Administration
Field Offices

*Created by UMTA reorganization of September 1973.

Figure 43. UMTA organizational structure.

SOURCE: Reference 27.

CAPITAL GRANTS. UMTA's greatest dollar impact is through its capital grants program. By law it may not award more than 12½ percent of any yearly capital grants authorized funding for projects in any one state. The Federal Highway Act of 1973 raised the federal share of net project cost from a discretionary two-thirds to a mandatory 80 percent. Table 90 shows major 1973 capital grants to the four cities of interest in this volume. Of the total $864 million in capital grants in that year, Philadelphia received $41 million as part of major improvement program focused on rail. Baltimore received $5 million to purchase one rail and three bus companies and for new buses. Los Angeles and Seattle each received about $2 million. Los Angeles' focus is on short-range auto alternatives and on the highway/transit tradeoff, while Seattle's more conventional program is directed to further consolidation of local transit companies and the addition of a park-and-ride lot for the successful "Blue Streak" express bus service.

UMTA's own evaluation of the impact of the capital grants program is relatively recent. In the year prior to March 1973, UMTA studied ridership in eight cities which were recipients of capital grants. According to a presentation of this study by UMTA administrator Herringer during testimony before Congress in March 1973 (3, pp. 734-5 and 770) annual ridership increases during the first year following capital grant award have ranged from 2-3 percent (Chicago, Baltimore, Dallas) to 20 or 30 percent (Springfield, Atlanta, Denver). Salt Lake City and Santa Barbara experienced 5 percent annual increases. The UMTA survey of these 8 cities concluded that:

1. Capital grants result in service improvements, not just in larger bus fleets. Area coverage is generally expanded or express buses introduced, for example.
2. Operating and maintenance costs are substantially improved, but overall financial results may not necessarily be.
3. While capital grant funded improvements can and do stimulate ridership increases, other factors, sometimes beyond management control, can counteract this positive effect. Examples cited are: general unemployment, fare increases, reduction of subsidy for student fares.

Clearly, the focus of the capital grant program, at least until recently, has been on improving transit service. The technical studies grants also serve this end, since they are usually awarded to help an agency develop a plan for which it intends to seek capital grant funding. These two programs'

Table 90. Major UMTA capital grants to agencies in Los Angeles, Philadelphia, Seattle, and Baltimore, 1973.

LOS ANGELES

$2 million to SCAG for Los Angeles Region Unified Work Program for short-range program to deal with EPA requirements to offer alternative to car and with highway/transit tradeoff.

1973 TOTAL: $2 million

PHILADELPHIA

$8.5 million to SEPTA for rehabilitation of Frankford elevated RR.

$984K to DVRPC for staggered work hours and parking rate hike program (Urban Corridor).

$31.2 million to Phila./Camden, Dela. River Port Auth., & SEPTA for new rail and bus equipment and stations, including Lindenwold improvements.

1973 TOTAL: $40.7 million*

SEATTLE

$800K to Cities of Seattle & Bremerton for Blue Streak parking lot (Seattle) and purchase of local carrier and new equipment (Bremerton).

$1 million to Seattle METRO to acquire MTC and refurbish bus fleet.

1973 TOTAL: $1.8 million

BALTIMORE

$4.9 million to Maryland DOT for purchase of B&ARR, 3 bus cos., 100 new buses, and facility rehabilitation.

1973 TOTAL: $4.9 million

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*Does not include a technical studies grant to DVRPC for Unified Work Program. This grant brings total funding for program to $434K.

SOURCE: Reference 28.

emphasis on transit has been a natural outgrowth of UMTA's interpretation of its function as stated in Section 2 of the UMT Act, "to assist in the development of mass transportation facilities . . ." to mean that it should by and large not concern itself with the private auto mode.

A recent shift in emphasis is suggested by the 1973 capital grant to Los Angeles to look at the highway/transit tradeoff in this highly auto-oriented city, and by the all-out DOT/UMTA/FHWA effort beginning in late 1973 to promote carpooling in addition to switching to transit as an energy-saving alternative

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to driving to work alone. To promote carpooling, UMTA personnel toured from city to city explaining carpooling techniques, and in January 1974 DOT issued nine special reports on various aspects of car and bus pooling, from matching procedures to incentives and legal and institutional issues. Certainly if one takes as the broader UMTA goal total urban mobility, both the transit/auto tradeoff and interface become important considerations.

R&D. UMTA's other major program effort, R&D, also seems to be undergoing a shift in emphasis.* Historically, RD&D has been hardware oriented. Of the roughly $150 million spent on RD&D projects through FY 1973, nearly 80 percent ($118 million) went to purely technological projects concerned with vehicle systems, hardware and software, and propulsion. Prior to the September 1973 reorganization, 13 of UMTA's 28 project managers were handling bus, rail, or new systems projects, almost all of which are technologically oriented, and which account for 52 of the 88 active projects and 16 of the 33 planned ones. Furthermore, fully 90 percent of funds devoted to technology has gone for vehicle hardware and propulsion and almost none has been spent on the design of terminals, ways and fixed equipment. The investment made has paid off in the development of new prototypes, such as the Transbus and Morgantown rail vehicles, and some long-range projects essential to the continuous and methodical development of technology, e.g., rail-supporting technology and the bus propulsion requirements study.

But perhaps even more important is what appears to be a stepped-up interest in transit operations and management, which are equally as important as capital equipment funding and hardware development in improving transit service levels and attracting new ridership. This increase in interest seems to be indicated by the creation of two new offices, as mentioned above, to handle transit planning and management. The latter office will oversee the recently announced $466,000 UMTA contract to develop marketing techniques for the transit industry (30, p. 1).

PROPOSED FEDERAL ENERGY GOALS AND PROGRAMS

As explained at the outset of this section, this report focuses primarily on EPA and UMTA goals with lesser emphasis being given to federal energy goals. Nonetheless it is necessary to have some understanding of the possible direction of federal energy policy in order to gain some insight into the implications for federal goals of the trends described in Section 2.

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*The following analysis is based on Reference 29, Vol. 2, "UMTA's RD&D Program: A Preliminary Evaluation."

The executive Office of Energy Policy was formed in July 1973 and the Federal Energy Office later that year. The FEO, which was succeeded in early 1974 by the Federal Energy Administration (FEA), brought together into a single administrative agency a diversity of programs and personnel. This new entity is still in search of a clearly defined overall program strategy. Of the recommendations for federal energy strategy which INTERPLAN reviewed, that of the former chairman of the AEC, Dr. Dixy Lee Ray, was the most authoritative and actionable (31). As Figure 44 indicates, the proposed strategy would make the U.S. totally self-sufficient in energy by 1985 by substituting increased production and conservation measures for oil imports. Five tasks are recommended to permit the U.S. to regain and maintain self-sufficiency; their contributions to self-sufficiency will begin to materialize in the order listed:

Task 1. Conserve energy by reducing consumption and conserve energy resources by increasing the technical efficiency of conversion processes.

Task 2. Increase domestic production of oil and natural gas as rapidly as possible.

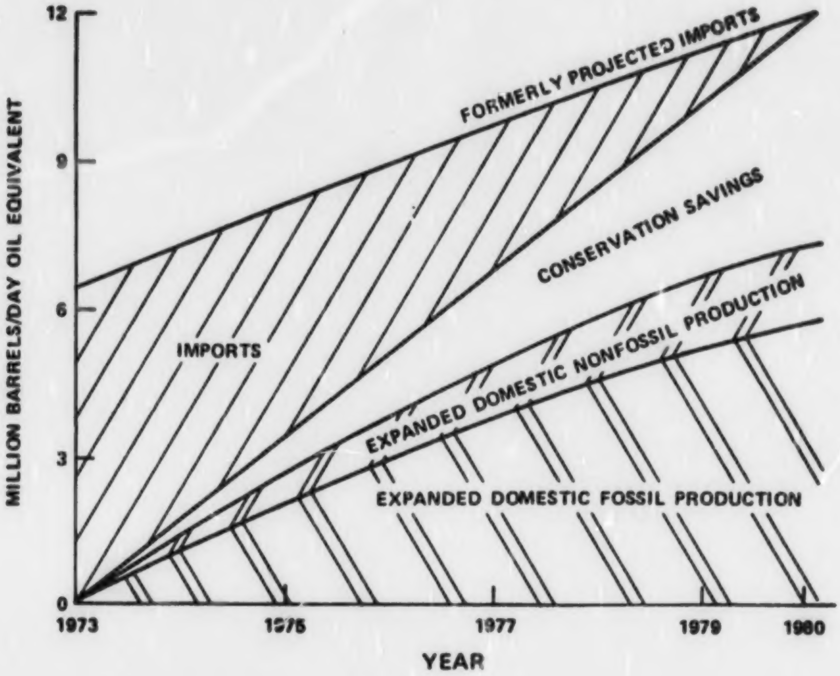
Task 3. Increase the use of coal, first to supplement and later to replace oil and natural gas.

Task 4. Expand the production of nuclear energy as rapidly as possible, first to supplement and later to replace fossil energy.

Task 5. Promote, to the maximum extent feasible, the use of renewable energy sources (hydro, geothermal, solar) and pursue the promise of fusion and central station solar power.

In view of the long lead times involved in Tasks 2 to 5, INTERPLAN believes that 1990 or 1995 may be a more realistic target date than 1985, but agrees with the premises of the Ray report, that present energy problems stem in large part from the lack of a coordinated national energy research and development program over the last 20 years (only nuclear power has received sustained support at adequate levels), and that the U.S. has the resources and technology for energy self-sufficiency.

The proposed program concentrates on short-term objectives and assumes a conservative contribution of R&D funds from private sources—energy suppliers



IMPORT REPLACEMENT (Million Barrels/Day Oil Equivalent)	YEAR	
	1973	1980
Formerly Projected Imports	6.5	12.0
Conservation Savings*		4.7
Expanded Domestic Nonfossil Production		1.5
Expanded Domestic Fossil Production		5.8

*Includes both conservation techniques and energy real price increases.

Figure 44. Self-sufficiency by 1980 through conservation and expanded production.

SOURCE: Reproduced from Reference 31, p. 46.

and the auto industry—to complement the recommended $10 billion, five-year federal budget. Table 91 shows the recommended total budget from 1975 to 1979 and an annual budget for 1975. The implementation of the recommended program would require establishing a new energy research and development administration by mid-1974 to coordinate federal and private efforts and to direct the federal portion.

Table 91. Energy R&D program and budget recommendations, FYs 1975-79. ($ millions)

Self-Sufficiency Tasks	ER&D Programs, FY 1975-1979 Total Required	ER&D Programs, FY 1975-1979 Private Expected	ER&D Programs, FY 1975-1979 Federal Recommended	Federal ER&D Budget FY 1974 Planned	Federal ER&D Budget FY 1975 Recommended
1. Conserve Energy and Energy Resources	4,940	3,500	1,440	62.3	166.2
2. Produce Oil and Natural Gas	4,960	4,500	460	19.5	51.7
3. Produce and Use Coal	5,175	3,000	2,175	167.2	405.0
4. Produce Nuclear Energy	5,340	1,250	4,090	517.3	731.7
5. Use Other Sources, Pursue Future Prospects	2,085	250	1,835	123.0	217.5
TOTAL	22,500	12,500	10,000	889.3	1,572.1

SOURCE: Reproduced from Reference 31, p. viii.

AREAS OF MUTUAL INVOLVEMENT

A more detailed investigation to pinpoint specific opportunities for interagency collaboration is presented in Volume 1 of this study. In the context of this review of the three agencies, it is appropriate simply to indicate the general areas of overlap and mention a few specific projects illustrating the areas of mutual involvement. Figure 45 shows the range of topics covered by the exist or planned program activities of UMTA, EPA, and FEA and the major overlaps as INTERPLAN sees them.

Examples of the agencies' activities in one area of direct EPA/UMTA overlap—changing travel habits—have been mentioned in the description of programs. The activities listed under this topic in the figure are among the transportation controls which EPA has been recommending to cities requiring reductions in vehicle miles traveled to meet the air quality standards.

Another major area of overlapping interest is vehicle propulsion systems. The EPA's air mobile source control technology R&D program includes testing of Rankine cycle, gas turbine, and stratified charge engines, and a comprehensive

<table>
<tr><td colspan="11">SPECTRUM OF TOPICS: URBAN TRANSPORTATION, AIR QUALITY, AND ENERGY</td></tr>
<tr><td colspan="6">URBAN MASS TRANSPORTATION ADMINISTRATION</td><td colspan="5"></td></tr>
<tr><td colspan="4"></td><td colspan="5">EPA—MOBILE AIR POLLUTION SOURCE CONTROL</td><td colspan="2"></td></tr>
<tr><td colspan="8"></td><td colspan="3">FEDERAL ENERGY AGENCIES*</td></tr>
<tr><td>Assure Passenger Safety</td><td>Serve Transportation Disadvantaged</td><td colspan="2">Improve Transit and Paratransit Service</td><td>Change Travel Habits</td><td colspan="2">Reduce Vehicle Emissions</td><td>Reduce Stationary Gasoline Evaporation</td><td colspan="3">Energy Independence by 1985</td></tr>
<tr><td></td><td></td><td>Improve management, planning & operating techniques</td><td>Improve equipment, facilities; build new systems</td><td>Increase transit ridership
Carpooling
Parking controls
Staggered work hours
Traffic restraints</td><td>Improve transit vehicle propulsion</td><td>Improve auto engine and enforce controls</td><td></td><td>Reduce petroleum consumption</td><td>Reduce electricity and natural gas consumption</td><td>Increased domestic production</td></tr>
</table>

*Objectives recommended by Ray report to President (Reference 31).

Figure 45. Spectrum of UMTA, EPA and federal energy program activities indicating areas of mutual involvement.

assessment of the status and prospects of alternative systems for auto propulsion. UMTA's work on bus propulsion systems over the past four years includes Rankine cycle testing for bus use (steam bus engine), evaluation of GM's transit bus retrofit kits, bus conversion to liquid natural gas fuel, a regenerative gas turbine engine for buses, a catalytic muffler for bus diesel engines, and a sodium-sulphur battery (32, pp. 33-36). UMTA has also participated in the interagency Transportation Energy R&D Goals Panel since the panel's inception in 1972 (32, p. 77).

TREND IMPLICATIONS FOR FEDERAL GOALS

UMTA, EPA, and FEA

The program activities described above serve to document that the federal government has already moved to take account of the impact of the trends in congestion, air pollution and energy use described in Sections 2 and 3. Thus it is less meaningful to ask, quoting from the work statement, "What are the consequences to federal government goals in urban mass transportation and urban air quality if no action is taken," than it is to ask, "What shifts in emphasis seem to be indicated by current trends?" All three areas of concern are currently alive with activity: UMTA is redirecting its programs following a major reorganization; EPA is promulgating and revising transportation control strategies for U.S. cities and grappling with the enforcement of vehicle emission requirements on auto manufacturers; FEA and other government bodies (Department of Interior, White House Energy Resources Council, Energy R&D Administration, and others) are working out a national energy program while coping with the immediate questions of short-range energy policy.

INTERPLAN's review of federal agency goals and program leads us to view the discernible shifts in current policy to be generally in line with the analysis of future trends. UMTA is recognizing the primacy of overall urban mobility as opposed to concentrating solely on transit. The importance of the auto-transit tradeoff is pointed to by the Section 2 (pp. 33-34) calculation of the cost of accommodating additional vehicle-miles traveled by building urban freeways: $45 billion for new construction and rights-of-way over the next 20 years to accommodate increases in urban motor vehicle travel. EPA, in turn, has been modifying its stand on the need for stringent transportation controls following the realization that the air in the U.S. will be cleaner in the next decade than it has been in the last two (22, p. 37) and that even in those areas still in excess of the standards in 1977, great reductions in air pollution will have been accomplished and most regions will be very near the standard. As an example, in December 1973, it reduced from 15 to 8 the number of urban areas that must limit gasoline use by 1977 (33, p. 1087). EPA Administrator Russell Train told a news briefing in December 1973 that the 60 to 80 percent emission reductions envisioned for the areas for which gasoline limitations had been proposed were probably too severe, and also noted that the timetable for the 1970 Clean Air Act would be postponed if Congress goes along with EPA recommendations (33, p. 1087).

Thus EPA is moving away from strict insistence on controlling areawide emission levels and back to the more basic goal of clean urban air within a reasonable time span. Even if the goal takes a few years longer than initially envisioned, the benefits should not be significantly diminished, and the monetary and social costs should be significantly reduced by eliminating the need for extreme, crash programs to meet the 1977 deadline. As stated in a 1973 EPA White Paper (22), "Compliance with air quality standards in these [14] regions [including Baltimore and Los Angeles] appears to require not only vehicle inspection and maintenance and the fullest possible vehicle retrofit, but also reductions in vehicle use of substantially more than 20 percent . . .. Achieving the air quality standards by 1977 is likely to require unreasonable changes in the present life styles of those regions and could result in the paralysis of entire urban areas." (p. 30). Thus it seems likely that legislative changes will be made to accommodate the need for additional compliance time for some cities.

As far as energy is concerned, the Ray report (31) amply directs attention toward the major shift in energy policy required by present trends in U.S. and world petroleum production, and by the recently demonstrated dangers of reliance on foreign oil. One issue which perhaps has not received the attention it is due is the energy cost in engine fuel economy losses due to changes to clean up vehicle emissions. The Ray report cites the lack of automotive engines that are both highly efficient and environmentally acceptable as a primary technological blockage to change (31, p. 63). However, this report also states that travel shifts to more energy efficient mass transportation systems could significantly reduce the total energy demand, if lack of general public acceptance of transit can be overcome (p. 62).

Therefore the ultimate impact on air quality and transportation goals of the transportation energy conservation objective to reduce projected transportation demand by about 5 percent by 1978 and 10 percent by the year 2000 depends on future modal split. The estimation of energy use impacts on the private/paratransit/transit tradeoffs and the examination of the preferred mix of transit modes are the subjects of Volume 2 of this study, directed to the question, "What further shifts in policy may contribute to a balanced joint attainment of energy, air quality, and urban transportation goals?"

Other Federal and Local Agencies and Private Industry

Although this study specifically considers the interests and involvement of only three agencies—UMTA and EPA because they are the joint cosponsors of this study, and FEA because its area of responsibility affects UMTA's and EPA's interests—INTERPLAN recognizes that other federal and local agencies and private industry must cooperate with these three agencies if their goals are to be attained. Even where the legislative authority to carry out a given program is clear, the goals well-defined, and program funding adequate, neither EPA nor UMTA can do the job alone.

In particular, the support of the Federal Highway Administration is important. The FHWA manages a network of vital importance to the U.S. economy: the federally sponsored highway system is vital to the auto, oil, and related industries, which generate one-fifth of the U.S. GNP. It is also among the oldest and best funded agencies within DOT and among federal agencies, and thus its powers are immense. If UMTA wishes to see, for instance, the widespread installation of ramp metering and construction of exclusive busways, FHWA will be the agency to implement them. In the long run, only FHWA's budget will be sufficient to electrify the highways to enable dual-mode systems to become a reality.

The cooperation of state and local transit and transportation authorities is required so that, for example, capital and operating subsidies are applied in such a way that service and ridership increase and that the results of UMTA's years of R&D work can be put to use. EPA requires the state air quality agencies to carry out its regulations, as described above.

Last but not least, the role of private industry is paramount in several key areas. For example, while FEA may proclaim the need to build more fuel-saving cars, unless Detroit makes up its mind to tackle the problem seriously, the result may simply be continued increases in imports of Japanese and European cars. If GM continues to limit the number of buses it manufactures, there is little that UMTA can do to increase the supply of buses. Even imports cannot solve the problem, since operators prefer domestically manufactured buses which are familiar to their mechanics. The introduction of electric cars for use in dual-mode systems will also be impossible unless industry becomes involved at the R&D stage. UMTA can provide some seed money, but this one project alone could easily consume UMTA's entire annual budget. It will surely take well-coordinated action by UMTA, FHWA, and EPA to see timely implementation of these new transportation technologies.

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APPENDIX A

WORK STATEMENT
JOINT EPA/UMTA/FEA STRATEGY FOR URBAN TRANSPORTATION AND AIR QUALITY

I. GENERAL WORK STATEMENT

Provide projections of current trends in traffic congestion, air pollution, and energy requirements if left unchecked until 2000; enumerate methods by which these trends could be reversed; and describe mutually supportive actions which could be implemented by UMTA and EPA toward accomplishing these reversals.

II. SPECIFIC OBJECTIVES

A. Review current information on traffic congestion, air pollution, and energy requirements associated with urban transportation.

B. Project the results of current trends in traffic congestion, air pollution, and energy requirements associated with urban transportation, by five year intervals to the year 2000, assuming no new federal programs will be enacted, and existing programs will remain active but not be expanded.

C. Describe the consequences relating to federal goals regarding urban mass transportation and air quality, if no new federal programs are enacted and existing programs are not expanded.

D. Enumerate changes that could offset the negative consequences projected in Objective B above and estimate the offsets of these changes, individually and in combination.

E. Determine key areas of interagency cooperation where EPA and UMTA can accomplish more by working together than they can by working independently; and categorize the specific actions they might take.

F. Determine the air pollution implications of various forms of mass transit UMTA now has under consideration, including magnetic levitation, tracked air cushion and over-the-water air cushion vehicles, hydrofoil, personalized rapid transit, dual mode vehicles, dial-a-ride, and increased use of taxis.

III. SPECIFIC WORK ITEMS

To achieve these objectives, the following work is required:

Task 1.a. Review current information on traffic congestion, air pollution, and energy requirements of urban transportation.

b. Project the results of current trends, if left unchecked, to 1975, from 1975 to 1980, 1980 to 1985, 1985 to 1990, 1990 to 1995, and 1995 to 2000.

c. Describe the consequences to federal government goals in urban mass transportation and urban air quality if no action is taken.

Task 2.a. Enumerate phenomena which could offset the negative consequences projected in Task 1.b.

b. Estimate the effects of these phenomena, individually and in combination. These phenomena shall include:

- Shift from private automobile to mass and para-transit.
- Communications as an alternative to urban travel.
- Rescheduling of urban activities to distribute urban travel.
- Technological improvements of urban transportation and air pollution control.
- The planned UMTA intermodal integration program.
- Shift in urban land use patterns so that the average number and length of trips are altered.

Task 3.a. Determine key areas wherein interagency cooperation would be more beneficial than independent agency action.

b. Recommend various joint strategies for EPA and UMTA.

c. Categorize specific, positive action which could be generated, promoted, or directed by UMTA and EPA according to impact.

It is expected that this study will provide information on, and/or justify further in-depth analysis of the areas specified in Tasks 4 through 6.

Task 4. The prospective impact of integrating dual mode into the present urban environment.

a. Determine the potential application of dual mode, the features needed for acceptance, and the total demand for such systems.

b. Determine the potential long and short term impact of dual mode transit systems on:

- The transportation mix and transportation efficiency of urban areas;

- The public, user and operator; and
- Pollution, congestion, and energy usage.

Task 5. UMTA and EPA: Energy Conservation Issues.

a. Prepare an order-of-magnitude estimate of the impacts of feasible tradeoffs among private, para-transit, and public transportation use on a national scale and in principal urban areas. These estimates should be particularly concerned with the following parameters:

- Volume of travel (especially peak-hour commuter travel).
- Number of private automobiles involved.
- Feasible number of public transportation vehicles (bus and rail) in 1973, 1975, 1980, 1985, 1990, 1995, and 2000.
- Resultant pollution levels.
- Feasible degree of compliance with the 1971 Clean Air Act.
- Implications on gas and lubricants consumption for urban transportation between 1973 and 2000 under various tradeoffs between number of private and public vehicles as mentioned above.

Task 6. Preferred mix of transit modes. Consequences and cost to the nation of congestion, pollution, and energy consumption.

a. Determine the air pollution and energy consumption implications of the various forms of transit modes now under consideration by UMTA, such as the tracked air-cushion vehicle, magnetic levitation vehicle, hydrofoils, personal rapid transit, dial-a-ride system, dual mode vehicles, and increased use of taxis.

b. Describe a method for analyzing the tradeoff among the various alternative transportation modes available, such as among the PRT, light rail, commuter rail, TACV, jitneys, etc., so as to arrive at a balanced mixture that would provide urban environments with an efficient total transportation system. The methodology must take into consideration the most important variables related to transportation, such as congestion, pollution, energy consumption, cost, certain aspects of land use, and labor and capital productivity in the years ahead.

APPENDIX B

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APPENDIX C

DATABASE FOR ESTIMATION OF INCREMENTAL VEHICLE-MILE COST

It is recognized that the estimating techniques used to obtain a measure of the annual incremental highway investments which had been made over the past 20-25 years per annual incremental increase in vehicle-miles traveled (documented here) is fairly crude when compared to the highly sophisticated techniques available. Probably the most accurate technique would have involved expressing the investment and vehicle-mile database as a set of coordinates corresponding to their position vis-à-vis an ordinate representing the magnitude of incremental investment per unit of time, and an abscissa representing incremental vehicle-miles per the same unit of time. The regression of the (y) parameter on (x) would then result in a mathematical expression of incremental investment as a function of incremental vehicle-miles. Differentiation of the expression would provide the desired marginal investment value. Alternatively, graphical solutions could have been applied to approximate the curve representing the dependence of incremental investment on incremental vehicle-miles and to determine the slope of the curve.

These more sophisticated techniques were rejected since they appeared to outweigh the sophistication of the underlying assumptions (i.e., that all increments or decrements in annual highway investments were directly related to annual changes in vehicle-miles traveled). In spite of these acknowledged deficiencies it is felt that the estimators which result can be considered as valid rule-of-thumb indicators of the highway costs which will be likely to be incurred due to additional vehicle-miles of highway travel. The database used in obtaining the estimates is documented below.

Separate adjustments to constant 1972 dollars (CY1972) were made for construction cost, maintenance and operation, and "all other" costs (administration and research, safety, patrol, interest on debt, debt retirement, and right-of-way acquisition). These factors and their source references are summarized in Table C-1.

Table C-2 documents the actual total expenditures on highways from 1950 to 1972 and expenditures for municipal systems for this period, to the extent that this data was available. Table C-3 shows the values of Table C-2 adjusted to 1972 dollar value. Table C-4 shows the vehicle-miles traveled on highways from 1950 to 1972 and annual changes. Incremental changes in highway expenditures (CY 1972) from 1950 to 1972 are given in Table C-5.

Table C-1. Deflators used to adjust highway investment costs to constant 1972 dollars.

Year	Construction Deflators[1]	Maintenance & Operation Deflators[1]	GNP Deflators[2]
1950	.49	.39	.54
1951	.61	.43	.56
1952	.63	.45	.58
1953	.60	.46	.60
1954	.57	.48	.61
1955	.55	.49	.62
1956	.63	.50	.63
1957	.66	.53	.66
1958	.65	.55	.69
1959	.62	.57	.70
1960	.60	.60	.71
1961	.60	.61	.71
1962	.63	.62	.72
1963	.65	.64	.73
1964	.66	.66	.74
1965	.68	.68	.76
1966	.71	.74	.78
1967	.75	.76	.81
1968	.77	.78	.84
1969	.83	.84	.88
1970	.93	.89	.83
1971	.99	.93	.97
1972	1.00	1.00	1.00

[1] Highway Statistics, Summary to 1965, DOT, FHWA, Bureau of Public Roads, March 1967, page 176; 1972 Selected Highway Statistics, DOT, FHWA, undated, page 11.

[2] Dept. of Commerce, Office of Business Economics, "The National Income and Product Accounts of the United States," 1929-1965; Statistical Abstracts of the U.S., 89th-94th annual editions (1968-1973), U.S. Department of Commerce, Bureau of the Census.

Table C-2. Total highway expenditures, municipal and rural, 1950-1972 ($ millions).

Year	MUNICIPAL AND RURAL			MUNICIPAL ONLY	
	Construction[1]	Maintenance & Operation	"All Other"[2]	Construction & Right-of-way	Maintenance & Operation
1950	2044	1423	1004	666	384
1951	2250	1557	1093	699	421
1952	2569	1652	1169	771	458
1953	2959	1734	1276	922	495
1954	3658	1804	1524	1106	518
1955	3857	1881	1617	1238	546
1956	4415	2089	1840	1511	621
1957	4933	2205	2165	1813	650
1958	5543	2369	2402	1970	704
1959	5754	2481	2643	2174	758
1960	5432	2640	2685	2131	797
1961	5855	2728	2904	2379	874
1962	6365	2839	3094	2787	918
1963	6917	2918	3208	2863	965
1964	7169	3060	3498	3136	1000
1965	7251	3232	3752	3056	1030
1966	7979	3516	4186	3326	1125
1967	8412	3771	4480	3468	1186
1968	9045	3910	4917	3771	1283
1969	9087	4245	5180	3535	1377
1970	10268	4720	5926	4164	1581
1971	10947	5101	6413	4676	1767
1972	11039	5433	6738	N/A	N/A

[1] Excludes right-of-way; 1956-1972, actual data; remaining data estimated at 89 percent of total capital outlay.

[2] Administration and research, safety, patrol, debt retirement, interest on debt and right-of-way.

Source: Highway Statistics, Summary to 1965, FHWA, DOT and annual issues to 1971; 1972 Selected Highway Statistics.

Table C-3. Total highway expenditures, municipal and rural, 1950-1972, adjusted to 1971-1972 constant dollars ($ millions).

Year	MUNICIPAL AND RURAL			MUNICIPAL ONLY	
	Construction[1]	Maintenance & Operation[2]	All Other[3]	Construction & Right-of-way	Maintenance & Operation
1950	4149	3401	1857	1352	918
1951	3668	3394	1946	1139	918
1952	4110	3420	2011	1234	948
1953	4882	3537	2105	1521	1010
1954	6438	3536	2499	1947	1015
1955	6981	3593	2557	2241	1043
1956	6975	3865	2907	2387	1149
1957	7449	3859	3291	2738	1138
1958	8536	3980	3507	3034	1183
1959	9264	4044	3779	3500	1236
1960	9126	4145	3786	3580	1251
1961	9661	4201	4065	3925	1346
1962	10057	4230	4301	4403	1368
1963	10652	4260	4363	4409	1409
1964	10897	4345	4722	4767	1420
1965	10659	4428	4953	4492	1411
1966	11250	4395	5358	4690	1406
1967	11272	4638	5555	4647	1459
1968	11758	4652	5851	4902	1527
1969	10995	4712	5905	4277	1528
1970	10987	4956	6400	4455	1660
1971	10473	5101	6605	4769	1767
1972	11039	5433	6738	N/A	N/A

[1] Excludes right-of-way.
[2] CY 1971
[3] See footnote (2), Table C-2.

Table C-4. Vehicle-miles traveled on highways and annual change, 1950-1972 (millions).

Year	MUNICIPAL AND RURAL		MUNICIPAL ONLY	
	Actual	Change	Actual	Change
1950	458,246		218,248	
1951	491,093	32,847	222,671	4,423
1952	513,581	22,488	224,118	1,447
1953	544,433	30,852	236,058	11,940
1954	561,963	17,530	247,551	11,493
1955	605,646	43,683	275,105	27,554
1956	631,161	25,515	287,200	12,095
1957	647,004	15,843	296,699	9,499
1958	664,653	17,649	307,069	10,370
1959	700,478	35,825	323,790	16,721
1960	718,845	18,367	331,585	7,795
1961	737,535	18,690	339,633	8,048
1962	766,852	29,317	368,089	28,456
1963	805,423	38,571	385,422	17,333
1964	846,500	41,077	405,086	19,664
1965	887,640	41,140	449,040	43,954
1966	930,497	42,857	469,777	20,737
1967	961,553	31,056	485,493	15,716
1968	1,015,649	51,096	513,289	27,796
1969	1,070,575	54,926	544,547	31,258
1970	1,120,705	50,130	577,373	32,826
1971	1,171,200	50,495	612,975	35,602
Average annual change (millions, CY 1972)		33,807		18,797

Table C-5. Annual change in highway expenditures (CY 1972, $ million).

Year	MUNICIPAL AND RURAL			MUNICIPAL ONLY	
	Construction[1]	Maintenance & Operation	All Other	Construction & Right-of-way	Maintenance & Operation
1951	- 481	- 7	89	-213	0
1952	442	26	65	95	30
1953	772	117	94	287	62
1954	1556	1	394	426	5
1955	543	57	88	294	28
1956	- 6	272	320	146	106
1957	474	- 6	383	351	- 11
1958	1087	121	216	296	45
1959	728	64	272	466	53
1960	- 138	101	7	80	15
1961	535	56	280	345	95
1962	396	29	236	478	22
1963	595	30	62	6	41
1964	245	85	359	358	11
1965	- 238	83	231	-275	- 9
1966	591	-33	405	198	- 5
1967	22	243	197	- 43	53
1968	486	14	296	255	68
1969	- 763	60	54	-625	1
1970	- 8	244	495	178	132
1971	- 514	145	205	314	107
1972	566	--	133	N/A	N/A
Average Annual Change ($million, CY 1972)	313	81	222	163	40

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[1] Excludes right-of-way.

APPENDIX D*

ASSUMPTIONS USED IN THE FORECAST OF UNITED STATES ENERGY CONSUMPTION THROUGH THE YEAR 2000

Gross National Product (GNP)

This is a comprehensive measure of aggregate economic activity. GNP measures final goods and services, eliminating intermediate products consumed in the production of end products. Because the use of energy is so intimately bound to economic activity, a forecast of GNP is necessary for forecasting energy demand. For purposes of this study the annual average rate of growth assumed was 4.3 percent to 1980, and 4.0 percent thereafter. The actual figures used are shown in table 3.

Population

The forecast was based on a population growth rate of approximately 1 percent. This is the midpoint of the D and E series estimated by the Bureau of Census.[1] The actual population figures used are shown in table 3.

Industrial Production

The forecast was based on a 5 percent annual rate of growth of industrial production up to 1980, and a 4.4 percent annual rate of growth thereafter. The actual index figures used are shown in table 3.

Fuel Availability

The forecast explicitly takes into consideration all supply limitations for fuels. The forecast is, therefore, a forecast of consumption, not demand.

Prices

It is expected that inflationary trends will raise the nominal prices of all fuels but that fuel prices, in general, will rise faster than other commodity prices. Additionally, intercommodity price relationships are expected to shift gradually, restructuring the relative price standings of the various fuels. The rate of increase in gaseous fuel prices is expected to be about 1.5 times the rate to be experienced in petroleum, and some 2.0 times the rate expected for coal.

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[1] U.S. Department of Commerce, Bureau of Census, "Population Estimates and Projections," Series P-25, No. 420, November 1971.

Table 3.—United States population, Gross National Product, and industrial productivity, 1971 actual, and projected to the year 2000

Year	Population[1]	Gross National Product (billions of 1958 dollars)[2]	Index of industrial production (1967 = 100)[3]
1971	206.9	739.5	106.5
1975	216.2	891	135
1980	229.4	1,102	177
1985	243.3	1,343	215
2000	279.7	2,438	413

[1] Population projection based on average of Series D & E projections contained in Bureau of Census publication P-25, No. 470, Nov. 1971.

[2] Projection based on 4.3 average annual growth rate to 1980, and 4.0 percent thereafter.

[3] Projection based on 5 percent average annual growth rate to 1980, and 4.4 percent thereafter. Projections constitute an extrapolation of the Federal Reserve Board Index of Industrial Production.

*Reproduced from U.S. Energy through the Year 2000, Walter G. Dupree, Jr. and James A. West, U.S. Dept. of Interior, December 1972, pp. 14-15.

Technology

The major change in energy technology expected between now and 1985 is development of commercial techniques for coal gasification and liquefaction and control of sulfur oxide emissions. Otherwise only evolutionary increases in the efficiency of utilization of energy were assumed for this period. The major technological change expected between 1985 and 2000 is commercial introduction of the breeder reactor.

Solar energy may supplant other energy sources for a small part of the home heating market. It is not forecast to assume any position in the production of electricity. Power from fusion is assumed to be so far in the future as to have no place in this forecast.

Lifestyle

The forecast assumes that the present slow trend toward a more service oriented economy will continue. The impact on energy consumption is considered minimal.

Methodology

The future energy requirements forecast in this paper were based upon a variety of forecasting techniques and the personal judgments of energy specialists in the Department of the Interior. Gross national product, population, manufacturing indices, and other basic economic data were correlated with energy consumption, and any important and consistent trends were extrapolated.

A three-pronged approach was used. Overall energy consumption was projected, as was individual energy consumption in the four sectors. The results were compared, and the differences reconciled. This was true of all sectors except electrical. Here the Federal Power Commission (FPC) projection through 1990 was used with an extrapolation of the trend to the year 2000.[1] Some minor modifications of the FPC projection were necessary to reconcile the differing formats.

Once total and sectorial energy consumption were established, the source of the energy was determined. It is here that supply constraints were recognized. Projections of energy supplies were made, and then the projections of energy use and supplies reconciled.

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[1] Federal Power Commission, 1970 National Power Survey.

APPENDIX E

DATA ON VEHICLE POPULATIONS, HIGHWAY CHARACTERISTICS, AND MODAL SPLIT IN LOS ANGELES, PHILADELPHIA, SEATTLE AND BALTIMORE

Table E-1. Vehicle population and usage distribution by model age for California at end of calendar year.

Model Year	Vehicle Age(yrs.)	Fraction of Population	Miles driven in last year (miles/year)	Fraction of Total Daily Auto VMT Driven
N+1	1/8	.027	15,000	.049
N	3/4	.107	14,500	.190
N-1	1-3/4	.104	12,500	.159
N-2	2-3/4	.101	10,650	.131
N-3	3-3/4	.097	9,300	.110
N-4	4-3/4	.092	8,050	.090
N-5	5-3/4	.086	6,575	.069
N-6	6-3/4	.079	5,225	.050
N-7	7-3/4	.069	4,850	.041
N-8	8-3/4	.059	4,350	.031
N-9	9-3/4	.041	4,200	.021
N-10 and older	over 9-3/4	.138	3,500	.059

Based on Reference 14, Section 3.

Table E-2. Data and projections of size and traffic on the highway system within the urbanized area of SCAG.*

	1972	1980	1990
Miles of Route:			
Interstate	300	344	360
Other principal arterials	2880	2924	3067
Minor arterials	3541	3634	3716
Collectors	2567	2700	2758
Local	16234	17284	19175
TOTAL	25522	26886	29076
Freeways	637	722	917
Other four or more lanes	2644	2870	3144
Less than four lanes (non local)	6007	5960	5840
Capacity Miles (10^3 Vehicle-Miles/Hour)**			
Interstate	1934	2125	2300
Other principal arterials	7824	8274	8862
Minor arterials	5042	5068	5321
TOTAL	14800	15467	16483
Freeways	3717	4371	5450

Projections of Vehicle Miles Traveled	1980		1990	
	Daily VMT (millions)	Fraction of Daily VMT	Daily VMT (millions)	Fraction of Daily VMT
Interstate	33.09	.183	37.29	.170
Other principal arterials	81.08	.450	105.27	.480
Minor arterials	37.07	.205	40.31	.184
Collectors	12.78	.071	16.21	.074
Local	16.46	.091	20.02	.092
TOTAL	180.48	1.0	219.09	1.0
Freeways†	63.2	.350	79.45	.363
Other four or more lanes	52.6	.291	66.8	.305
Less than four lanes (non local)	48.2	.267	52.9	.241

*The urbanized area of SCAG and the LARTS area are virtually synonomous.

**Capacity miles are determined by multiplication of miles of route times the one way hourly capacity at level of service E as defined by the Highway Capacity Manual.

†Freeways include Interstate and about 42% of arterial VMT.

Source: Reference 7, Section 3.

Table E-3. Data and projections of traffic on the highway system within the urbanized area of the Delaware Valley regional planning commission area.

	Daily Travel (10^6 VMT/Day)			Fraction of Daily VMT			Average Speeds (mph)		
	1972	1980	1990	1972	1980	1990	1972	1980	1990
Functional Classification:									
Interstate	5.85	10.49	16.46	.099	.138	.169	48.5	48.6	49.2
Other principal arterials	23.08	29.39	36.90	.391	.388	.379	27.8	32.4	36.1
Minor arterials	11.62	12.75	14.01	.197	.166	.144	22.1	24.6	28.0
Collectors	4.66	5.96	7.47	.079	.079	.078	21.2	23.2	25.2
Local	13.72	17.32	22.42	.232	.228	.230	18.2	20.5	22.6
TOTAL	58.93	75.91	97.26	1.0	1.0	1.0	24.3	27.8	31.2
Design Type:									
Freeways	11.81	29.19	36.54	.200	.222	.376	46.6	46.7	47.4
Other 4 or more lanes	21.79	24.08	25.52	.369	.317	.261	24.0	26.6	28.8
Less than 4 lanes (non local)	11.61	12.38	12.98	.197	.163	.133	21.7	23.7	27.2

Based on Reference 16, Section 3.

Table E-4. Data and projections of length and capacity on the highway system within the urbanized area of the Delaware Valley Regional Planning Commission area.

	1972	1980	1990
Miles of Route			
Interstate	128.8	224.2	233.6
Other prin. arterials	1,198.2	1,264.7	1,330.2
Minor arterials	1,381.2	1,424.9	1,428.0
Collectors	1,122.0	1,141.0	1,130.0
Local	7,087.6	8,303.7	9,478.0
TOTAL	10,917.8	12,358.6	13,599.8
Freeways	317.1	464.7	540.9
Other 4 or more lanes	1,545.0	1,577.1	1,596.2
Less than 4 lanes (non local)	1,968.1	2,013.1	1,984.7
Capacity Miles (10^3 Vehicle - Miles/Hr)			
Interstate	725.0	1,261.3	1,406.9
Other prin. arterials	2,233.9	2,545.5	2,823.0
Minor arterials	1,220.1	1,281.3	1,292.7
TOTAL	4,179.0	5,088.1	5,522.6
Freeways	1,684.0	2,495.1	3,066.7

Based on Reference 16, Section 3.

Table E-5. Age and average annual VMT distributions for automobiles and trucks in Philadelphia for July 1, 1971.

Age (yrs)	Automobile			Truck		
	Age Distribution	Annual VMT	Composite Factor	Age Distribution	Annual VMT	Composite Factor
0	.08	5,468	.042	.07	5,316	.033
1	.11	15,433	.161	.11	15,174	.149
2	.11	13,200	.138	.13	15,800	.184
3	.11	11,400	.119	.10	15,800	.141
4	.10	11,700	.111	.09	13,000	.105
5	.10	10,000	.095	.07	13,000	.081
6	.10	10,300	.098	.07	11,000	.069
7	.08	8,600	.065	.06	11,000	.059
8	.08	10,900	.083	.06	9,000	.048
9	.05	8,000	.038	.04	9,000	.032
10	.03	6,500	.019	.03	5,500	.015
11	.02	6,500	.013	.03	5,500	.015
12	.01	6,500	.006	.02	5,500	.010
Over 12	.02	6,500	.012	.12	5,500	.059
	1.00	10,521	1.000	1.00	11,185	1.000

Source: Delaware Valley Regional Planning Commission. Derivation of Emission Factors for Calculation of Motor Vehicle Pollutant Emissions in the City of Philadelphia. Revision B. Report No. EC-H-1, Philadelphia, April 1973.

Table E-6. Daily person-trip modal-split data on Philadelphia.

A. Daily person trips for Pennsylvania portion of DVRPC area.

	1972	1990
Total trips	11,875,456	16,226,576
Percent by highway	87.9	86.7
Percent by taxi	0.7	0.7
Percent by bus	5.5	7.1
Percent by rail	5.9	5.5

Source: DVRPC unpublished data.

B. Daily person-trip origins by mode of travel by area. (thousands of trips)

AREA	MODE OF TRAVEL								
	Auto Driver	Auto Pass.	Total Auto	Rail-road	Subway-El	Bus & Trolley	Total Transit	Total	Percent Transit
Center City	114	46	161	28	94	106	228	389	58.6
Remainder of City	1,413	680	2,093	20	254	512	786	2,879	27.3
Total City	1,527	726	2,253	48	348	618	1,015	3,268	31.1
City of Camden	137	70	206	--	5	37	42	248	16.9
City of Trenton	160	81	241	1	--	18	19	261	7.3
Pa. Suburbs	1,623	824	2,446	34	34	87	156	2,602	6.0
New Jersey Suburbs	861	468	1,330	2	4	47	52	1,382	3.8
Total Cordon Area[1]	4,309	2,168	6,477	85	390	808	1,283	7,760	16.5
Percent	55.5	27.9	83.5	1.1	5.0	10.4	16.5	100.0	

[1] Totals may not add due to rounding.

C. Relative use of travel modes by destination area and purpose of trip.

Destination Area	PERCENT USING TRANSIT[1] BY PURPOSE TO			
	Home	Work	All Other Purposes	All Purposes
Center City	50.4	63.2	53.2	58.6
Remainder of City	34.9	25.2	19.4	27.3
Total City	35.2	34.4	24.0	31.1
City of Camden	20.9	19.0	12.1	16.9
City of Trenton	8.6	9.4	5.4	7.3
Pa. Suburbs	8.3	7.1	3.4	6.0
New Jersey Suburbs	5.9	3.7	1.7	3.8
Total Cordon Area	18.9	22.7	11.0	16.5

[1] Excludes school bus and truck and taxi passengers.

D. Daily person-trips by purpose and mode of travel. (thousands)

Trip Purpose To To	Trips by Auto[1]	Trips by Transit[2]	Total Trips	Percent by Transit
Home	2,504	585	3,089	18.9
Work	1,217	357	1,574	22.7
Shop	573	58	631	9.2
School	108	78	186	41.9
Social-Recreational	1,022	92	1,114	8.3
Personal Business	785	101	886	11.4
Other	268	13	281	4.6
Total[3]	6,477	1,283	7,760	16.5

[1] Auto drivers and passengers.

[2] Railroad, Subway-Elevated, Bus and Trolley Trips; Does not include 252,500 trips by school bus.

[3] Totals may not add due to rounding.

Source for B-D: Penn-Jersey Transportation Study. Internal Trip File Nos. 7068 and 7069. Philadelphia, 1964.

Table E-7. Vehicle mix and classification, Puget Sound Region.*

	Puget Sound Region			Statewide
	King**	Pierce***	Snohomish∇	
1971 REGISTRATION				
Gasoline, light duty	83.3%	80.6%	76.0%	79.1%
Gasoline, heavy duty	16.2	19.2	22.7	20.5
Non-gasoline	0.5	0.2	1.3	0.4
TOTAL	100.0%	100.0%	100.0%	100.0%
STUDY YEAR		1961		
Daily vehicle trip:				
Auto		87.4%		
Truck		12.6%		
TOTAL		100.0%		
DAILY VMT				
Gasoline, light duty		88.8%		
Gasoline, heavy duty		9.1		
Non-gasoline		2.1		
TOTAL		100.0%		

*Not including motorcycles.
**Seattle, Renton, Bellevue.
***Tacoma.
∇Everett.

Source: Reference 23, Section 3.

Table E-8. Vehicle age distribution for early 1972, King & Pierce Counties, Washington.

Model Year	King County (percent)	Pierce County (percent)
72	3.73	3.75
71	7.25	7.10
70	7.46	7.21
69	9.91	9.13
68	9.94	9.20
67	9.83	9.05
66	10.05	9.44
65	9.36	9.40
64	7.48	8.04
63	6.56	6.94
62 & prior	18.31	20.75
TOTAL	100.0%	100.0%
Total number of vehicles	440,121	136,610
NOTE: The Puget Sound Region has been experiencing high unemployment rates among middle-class families; therefore it can be expected that the purchasing of new vehicles would be down. The above distribution seems to reflect this trend.		

Based on Reference 23, Section 3.

Table E-9. Data and projections of motor vehicle populations for Baltimore.

A. Motor vehicle registrations for Baltimore.

Year/Type	Baltimore City	SMSA
1970		
Pleasure	259,731	788,689
Total	316,334	958,445
1972		
Pleasure	250,430	772,165
Total	299,265	946,081

Source: Department of Motor Vehicles, State of Maryland.

B. Automobile ownership projections for Baltimore City.

Year	Auto Owners
1970	219,200
1980	312,400
1995	368,800

Source: Maryland Department of Transportation.

Table E-10. End of year distributions of VMT by vehicle age, Baltimore.

	POLK DATA USED IN PRESENT STUDY				MARYLAND STATE DATA	
	Passenger Cars		Trucks		All Vehicles	
Vehicle Age (years)	Vehicle Distribution(a) (Percent)	Average Travel(b) (Miles)	Vehicle Distribution(a) (Percent)	Average Travel(b) (Miles)	Vehicle Distribution(c) (Percent)	Average Travel(c) (Miles)
0	3.2	3,600	3.0	3,500	4.1	3,300
1	12.2	11,900	10.8	11,700	11.8	12,900
2	15.8	16,100	13.5	17,200	11.5	11,750
3	11.9	13,200	10.7	15,800	10.5	10,650
4	10.2	11,400	8.3	15,800	9.3	9,550
5	9.3	11,700	8.1	13,000	9.5	9,225
6	9.1	10,000	7.7	13,000	9.2	8,675
7	8.2	10,300	6.4	11,000	7.7	8,475
8	6.7	8,600	5.3	11,000	6.5	7,900
9	5.0	10,900	4.2	9,000	6.0	7,225
10	3.2	8,000	3.3	9,000	5.0	6,675
11	1.8	6,500	2.5	5,500	4.0	5,200
12	1.1	6,500	2.2	5,500	4.9	4,500
13	2.3	6,500	14.0	5,500		
	100.0		100.0		100.0	

(a) GCA Adjustment to R.L. Polk data

(b) Kircher & Armstrong, 1972, quoting AMA Publications

(c) Maryland BAQC Modification of data in Table B-2

(d) Bureau of Public Roads data quoted by Maryland BAQC

Source: Reference 26, Section 3.

Table E-11. Modal split estimates for the City of Baltimore in thousands of person trips and percentages.

Time/Mode	1972		1980		1995	
	Trips	Percent	Trips	Percent	Trips	Percent
Daily						
Highway	420.49	81.1	1238.32	83.2	1672.71	79.8
Driver	287.72		851.25		1133.81	
Transit	98.07	18.9	249.40	16.8	422.26	20.2
TOTAL	518.57	100.0	1487.72	100.0	2094.97	100.0
Peak Period						
Highway	90.08	79.1	226.05	76.3	287.73	71.6
Driver	51.38		154.32		211.57	
Transit	23.77	20.9	70.15	23.7	114.36	28.4
TOTAL	113.85	100.0	296.20	100.0	402.09	100.0

Source: Maryland Department of Transportation.

APPENDIX F

DATA ON EMISSION STANDARDS AND EMISSION FACTORS FOR LOS ANGELES, PHILADELPHIA, AND BALTIMORE

Table F-1. Current light duty and heavy duty vehicle new model maximum emission standards (gms/mi) for California

Model Year	Exhaust CO	Exhaust NO_2	Exhaust HC*	Crank and Evap HC**
Light Duty Vehicle				
Pre-1961	124	7.1	16.3	7.08
1961-1963	124	7.1	16.3	3.816
1964	110	6.4	13.1	3.0
1965	96	5.7	9.5	3.0
1966-1967	62	7.1	9.5	3.0
1968-1969	50	7.1	5.6	3.0
1970	35	5.5	3.5	0.49
1971	35	4.4	3.5	0.49
1972	31	4.4	3.1	0.16
1973	31	2.7	3.1	0.16
1974-1975 †	31	1.7	3.1	0.16
1976 †	4.7	1.2	0.46	0.16
1977	4.1	0.5	0.4	0.16
1978 and on	4.1	0.4	0.4	0.16
Heavy Duty Vehicle				
Pre-1967	129	9.5	18.7	8.2
1968-1969	129	9.5	18.7	3.0
1970-1971	80	9.5	15.1	3.0
1972	53	9.5	9.9	3.0
1973-1975	43	9.5	7.8	0.8
1976	30	3.3	2.4	0.8
1977 and on	27	3.0	2.4	0.8

*Reactivity Factor = .8
** Reactivity Factor = .67

Sources: References 8 and 19, Section 3.

†Current interim standards factors are:

	CO	NO_2	HC
1974	28.0	2.0	2.8
1975	15.0	3.1	1.5
1976	3.4	0.4	0.41

The factors in Table F-1 were used, since the above interim standards factors were not available at the time of calculation.

Table F-2. Light duty vehicle fleet average emission factors in the Los Angeles area at end of calendar year.
(gms/mi)

Year	Exhaust CO	Exhaust NO_2	Exhaust HC	Crankcase & Evaporative HC	Total HC	Highly Reactive HC
1970	65.74	6.82	8.37	2.69	11.06	8.50
1972	52.20	5.65	6.71	1.66	8.37	6.48
Case A:	1976 control standards imposed as scheduled:					
1975	38.35	3.66	4.75	.79	5.53	4.33
1977	23.57	2.50	3.31	.51	3.81	2.98
1980	13.58	1.32	1.79	.32	2.11	1.64
1985	6.13	.61	.86	.20	1.06	.82
1990	4.66	.45	.65	.17	.82	.64
2000	4.13	.40	.55	.16	.71	.55
Case B:	Only current active standards maintained; 1976 controls not imposed:					
1975	39.64	3.68	4.88	.79	5.66	4.43
1977	34.18	2.87	4.38	.51	4.89	3.84
1980	33.13	2.18	3.86	.32	4.18	3.30
1985	31.51	1.82	3.61	.20	3.81	3.02
1990	31.13	1.73	3.56	.17	3.73	2.96
2000	31.01	1.70	3.54	.16	3.70	2.94

Emission factors reflect emission controls for specific model years, model population and travel distribution by age, and deterioration of controls with age.

Source: Calculated by INTERPLAN.

Table F-3. Average vehicle mile emission factors for light duty and heavy duty vehicles in the Los Angeles area at end of calendar year. (gms/mi)

Year	Exhaust CO	Exhaust NO_2	Total HC	Highly Reactive HC
1970	68.69	6.96	11.77	8.96
1972	55.13	5.80	9.11	7.05
Case A: 1976 control standards imposed as scheduled:				
1975	40.69	3.95	6.16	4.81
1977	25.80	2.78	4.36	3.41
1980	15.36	1.57	2.50	1.95
1985	7.63	.78	1.32	1.03
1990	5.97	.61	1.04	.80
2000	5.34	.54	.90	.69
Case B: Only current active standards maintained; 1976 controls not imposed:				
1975	41.93	3.99	6.29	4.91
1977	36.03	3.21	5.45	4.28
1980	34.33	2.56	4.63	3.65
1985	31.69	2.22	4.22	3.34
1990	31.84	2.13	4.10	3.25
2000	31.64	2.11	3.91	3.22
Assumes 5.2% of vehicle miles traveled in the Los Angeles area are by heavy duty vehicles.				

Source: Calculated by INTERPLAN.

Table F-4. Vehicle emission factors for low altitude cities (gms/mi).

Model Year	Exhaust CO	Exhaust NO_x	Exhaust HC	Crankcase and Evaporative HC
LIGHT-DUTY VEHICLES:				
Pre-1961	124	7.1	16.3	7.1
1961-63	124	7.1	16.3	3.8
1964-65	87	3.6	8.8	3.0
1966	51	3.4	6.0	3.0
1967	50	3.4	4.6	3.0
1968	46	4.3	4.5	3.0
1969	39	5.5	4.4	3.0
1970	36	5.1	3.6	0.5
1971	34	3.5	2.9	0.5
1972	19	3.5	2.7	0.2
1973-74	19	2.3	2.7	0.2
1975	2.8	1.6	0.33	0.2
1976 and on	1.8	0.31	0.23	0.2
HEAVY-DUTY VEHICLES:				
Pre-1967	140	9.5	18.7	8.2
1968-69	140	9.5	18.7	3.0
1970-72	130	9.2	16	3.0
1973	130	9.2	16	0.2
1974 and on	130	9.2	13	0.2

Source: Kircher, David S., and Donald P. Armstrong. *An Interim Report on Motor Vehicle Emission Estimation.* Environmental Protection Agency, Office of Air and Water Programs, Research Triangle Park, N.C., Publication No. EPA-450/2-73-003, October 1973.

Table F-5. Weighted age and travel factors for vehicles.

Age (years)	Light-Duty Vehicles	Heavy-Duty Vehicles
0	0.013	0.003
1	0.075	0.095
2	0.174	0.164
3	0.135	0.121
4	0.103	0.114
5	0.115	0.097
6	0.097	0.088
7	0.083	0.064
8	0.060	0.054
9	0.059	0.036
10	0.027	0.028
11	0.017	0.018
12	0.010	0.015
13 and older	0.032	0.103

Table F-6. Carbon monoxide deterioration factors for light-duty gasoline-powered vehicles in all areas except California.

	Vehicle age,[a] years								
Model year	1	2	3	4	5	6	7	8	9 and older
1967 and earlier	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1968	1.24	1.35	1.41	1.47	1.53	1.58	1.63	1.67	1.72
1969	1.42	1.53	1.59	1.63	1.68	1.71	1.75	1.79	1.82
1970 through 1974[b]	1.18	1.32	1.38	1.40	1.44	1.47	1.50	1.51	1.56
1975[c]	1.04	1.30	1.36	1.43	1.44	1.49	1.56	1.63	1.69
1976 and later	1.34	1.77	2.14	2.42	2.73	2.99	3.26	3.48	3.77

[a] "0"-year-old vehicles have a deterioration factor of 1.00.

[b] Based on test results for 1970 model year vehicles.

Source: Same as Table F-4.

Table F-7. Exhaust hydrocarbon deterioration factors for light-duty gasoline-powered vehicles in all areas except California.

	Vehicle age,[a] years								
Model year	1	2	3	4	5	6	7	8	9 and older
1967 and earlier	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1968	1.12	1.18	1.21	1.23	1.26	1.28	1.30	1.32	1.35
1969	1.10	1.16	1.18	1.21	1.23	1.25	1.28	1.29	1.31
1970 through 1974[b]	1.05	1.10	1.13	1.15	1.17	1.20	1.22	1.24	1.26
1975[c]	1.00	1.13	1.22	1.29	1.37	1.43	1.50	1.56	1.63
1976 and later	1.45	1.95	2.40	2.76	3.14	3.46	3.79	4.07	4.42

[a] "0"-year-old vehicles have a deterioration factor of 1.00.

[b] Based on test results for 1970 model year vehicles.

Source: Same as Table F-4.

Table F-8. Nitrogen oxide deterioration factors for light-duty gasoline-powered vehicles in all areas except California.

	Vehicle age,[a] years								
Model year	1	2	3	4	5	6	7	8	9 and older
1972 and earlier	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1973 through 1974[b]	1.11	1.18	1.20	1.21	1.22	1.23	1.24	1.25	1.26
1975	1.00	1.18	1.23	1.23	1.41	1.45	1.45	1.45	1.45
1976 and later	1.34	1.77	2.14	2.42	2.73	2.99	3.26	3.48	3.77

[a] "0"-year-old vehicles have a deterioration factor of 1.00.

[b] Based on test results for 1971 (California) model year vehicles.

Source: Same as Table F-4.

Table F-9. Average emission factors for motor vehicle sources in grams per mile.

Location/Time/Mode		CO	NO_x	HC (Exhaust)	HC (Other)	Total HC
DVRPC Area (Source 31) Overall:						
1972		72.5	6.2	--	--	11.6
1980		13.4	1.95	--	--	4.35
1990		8.26	.91	--	--	1.08
City of Philadelphia (Source 35):*						
1972	Automobiles	66.04	4.33	6.15	2.99	9.14
	Trucks**	121.24	8.13	14.91	4.35	19.26
	Overall†	71.45	4.70	17.31	3.12	20.43
1985	Automobiles	7.04	.87	.75	.20	.95
	Trucks	116.06	12.38	11.97	.70	12.67
	Overall	7.60	1.98	.79	.25	1.04

*Factors calculated for July 1 of each year.

**Truck emission factors assume 87% of trucks are gasoline-powered and 13% are diesel.

†Overall factor assumes 90.3% of VMT are due to automobiles and 9.7% are due to trucks.

Table F-10. Average motor vehicle emission factors (gms/mi) implied in various emission projections.

A. 1970/77 projections for BMATS in Transportation Controls Study.

Vehicle type	CO		HC	
	1970	1977	1970	1977
Light duty	61.02	19.74	9.54	2.70
Heavy duty	124.0	86.27	24.18	15.18
Diesel	20.41	20.37	3.36	3.35
Overall average	66.78	28.06	10.92	4.27

Source: Reference 26, Section 3.

B. BMATS baseline projections - all vehicles.

Pollutant	Inside Beltway Average			BMATS Region Average		
	1972/73	1980	1995	1972/73	1980	1995
CO	104.76	24.55	10.26	51.50	12.13	5.56
HC	19.51	3.57	1.66	10.26	1.69	.84
NO_x	9.21	3.75	1.67	5.33	1.95	.87

Source: Reference 29, Section 3.

C. Baltimore SMSA urban areas.

Pollutant	1972	1980	1990
CO	68.49	24.54	6.71
HC	12.16	3.27	.73
NO_x	6.67	3.58	.45

Source: Reference 28, Section 3.